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THE INSTITUTION OF PRODUCTION ENGINEERS

JOURNAL

(February, 1947, Vol. XXVI, No. 2.)

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by SIR CLAUDE GIBB, F.R.S., M.I.Mech.E., M.I.P.E.

"THE IMPORTANCE OF STANDARDISATION"
by J. E. BATY, M.I.P.E.

"PRODUCTION OF BEVEL GEARS"
by G. W. NASH, Esq.

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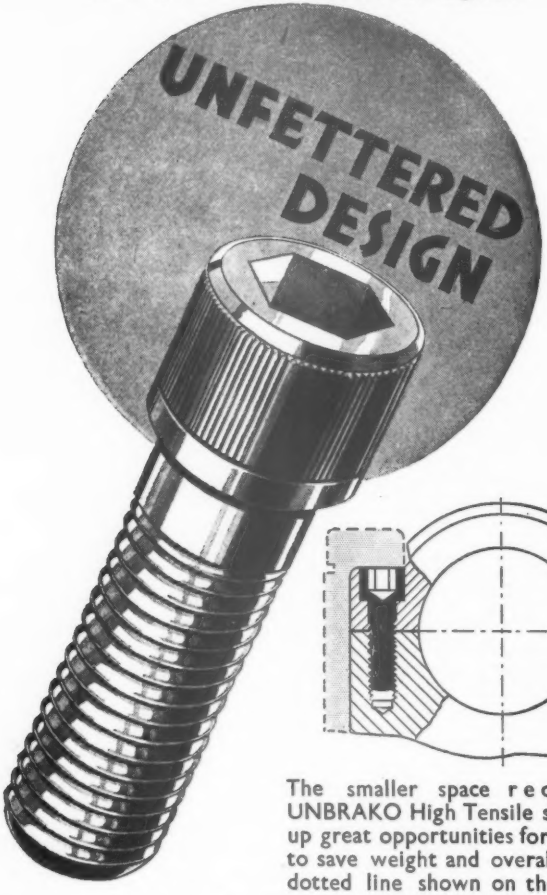

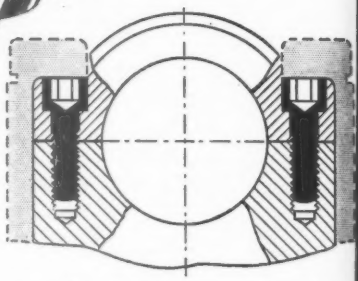

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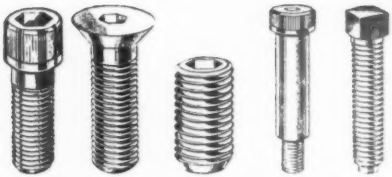

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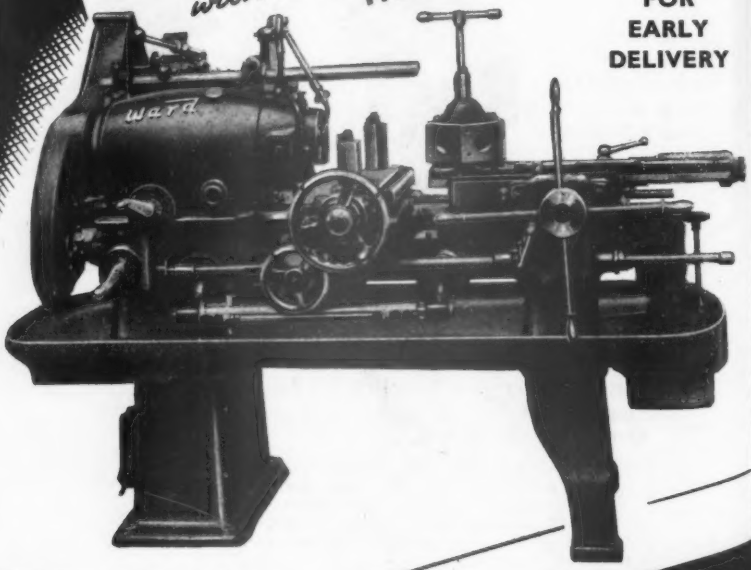

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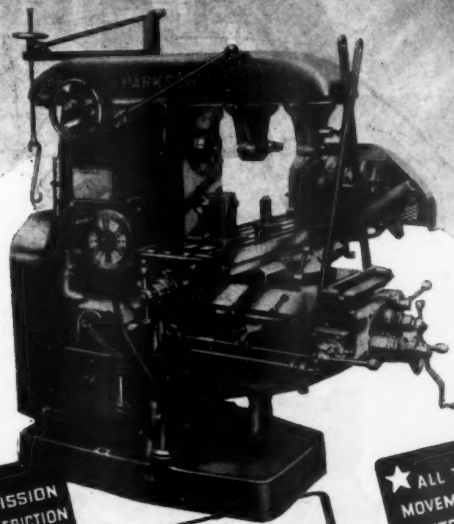

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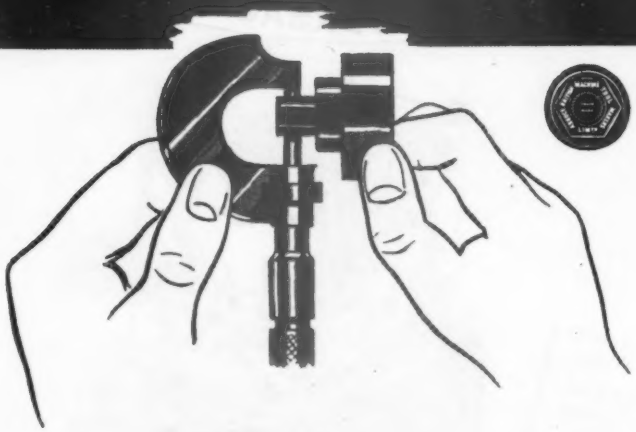

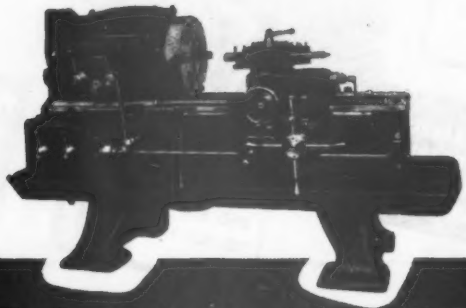

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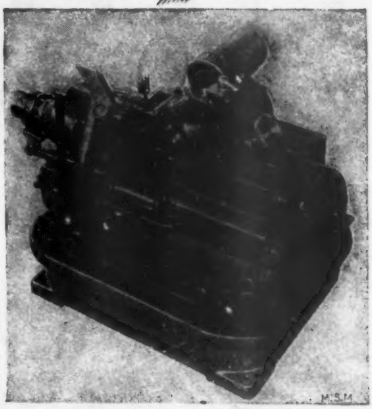

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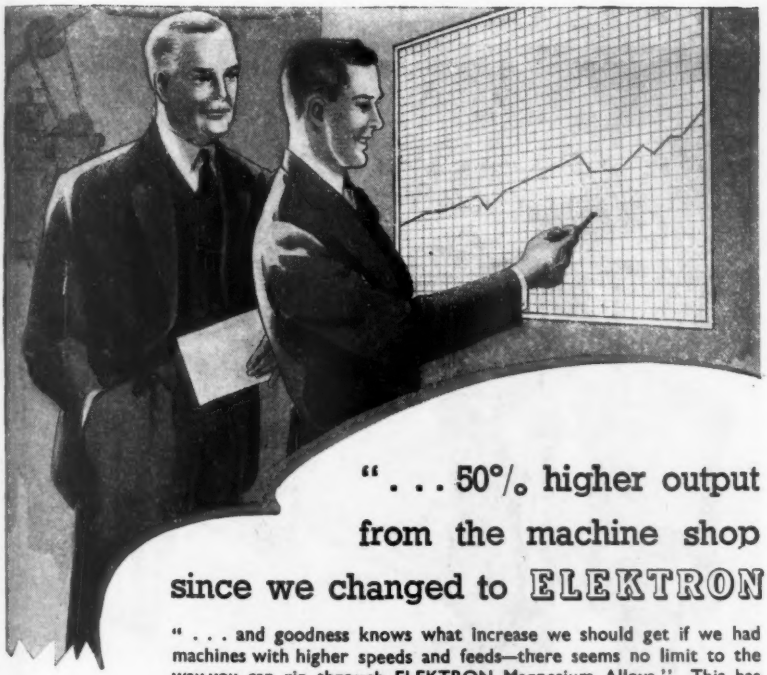

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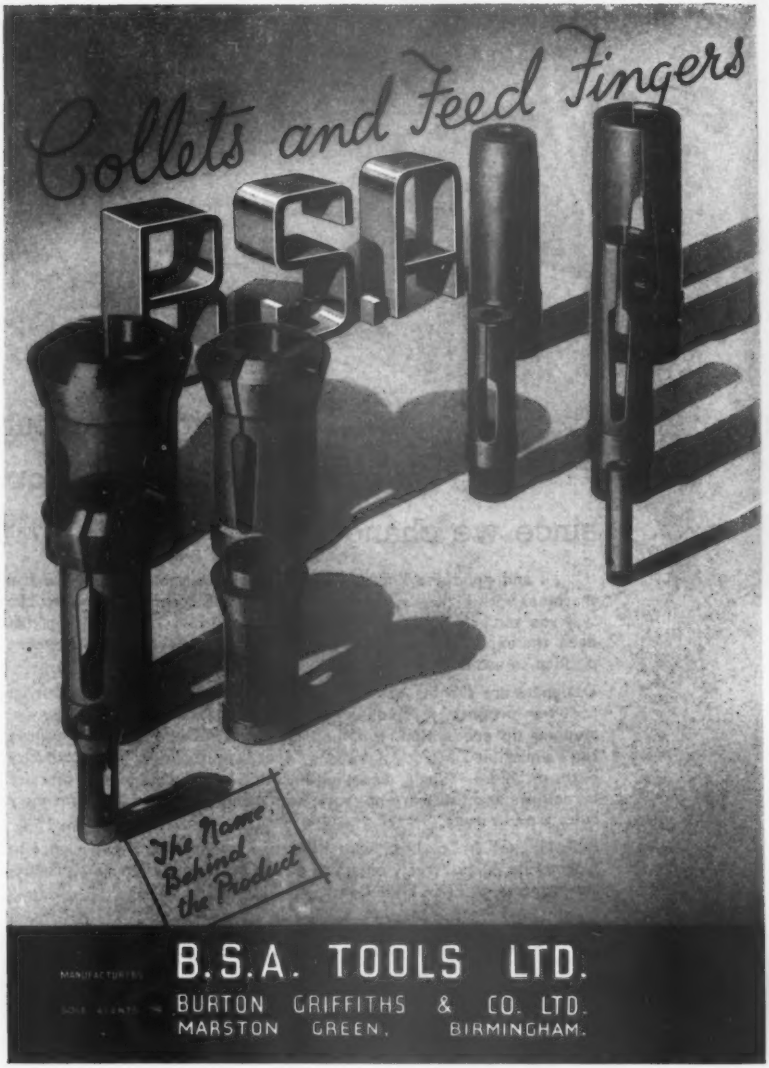
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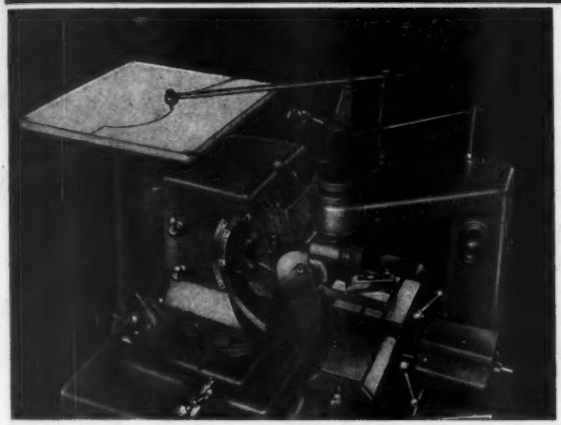

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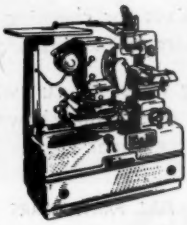

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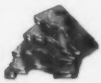

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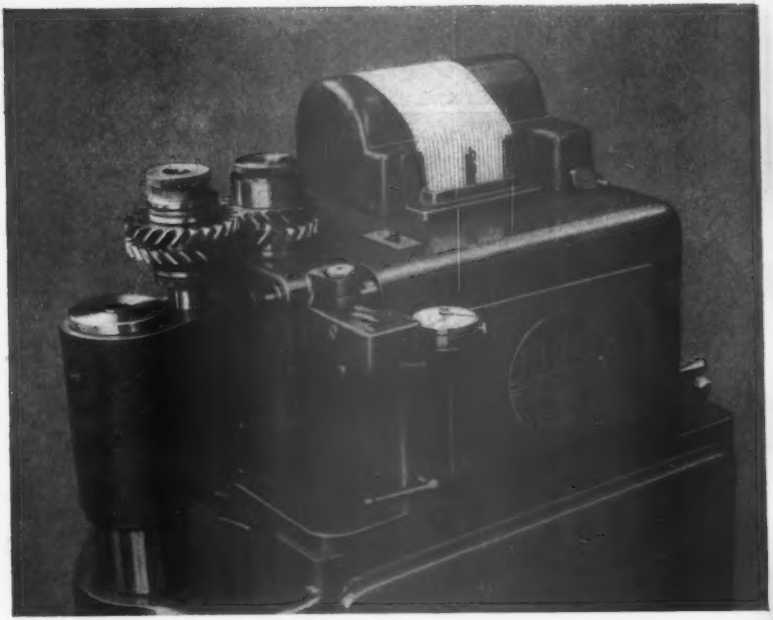

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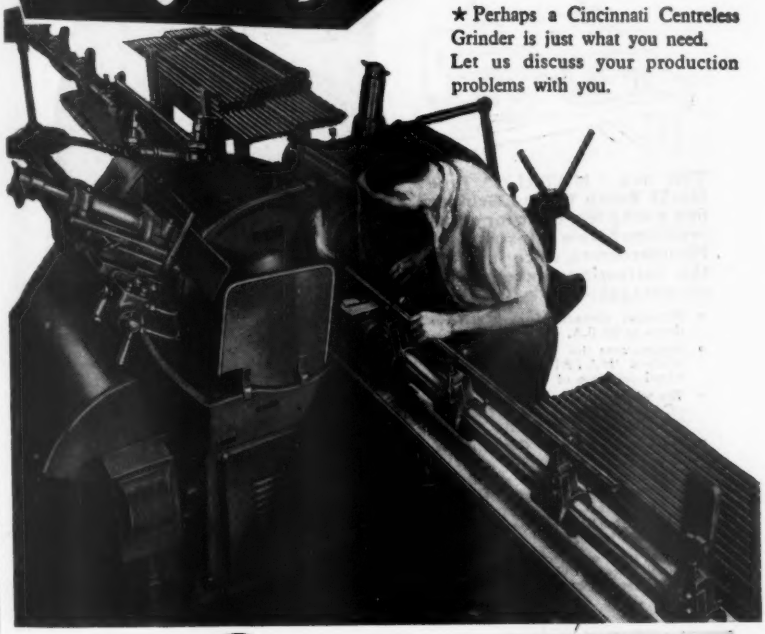

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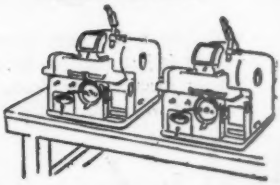

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INSTITUTION NOTES

February, 1947

February Meetings

3rd Yorkshire Section. A lecture on Production Engineering Research will be given by Dr. D. F. Galloway, B.Sc.(Hons.)., A.M.I.Mech.E., A.M.I.E.E., M.I.P.E., in the Assembly Hall, Grammar School, Keighley, at 7-0 p.m.

3rd Coventry Graduate Section. A discussion meeting on "The Ideal Training for a Production Engineer" will be held at the Coventry Technical College, Coventry.

7th Leicester and District Section. A Joint Meeting has been arranged with the Leicester Association of Engineers, to take place at the College of Technology, Leicester, at 7-0 p.m., when the following sound films will be shown: (1) "The Production of Pluto"; (2) "Through the Mill."

11th Birmingham Graduate Section. There will be a meeting at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m., when "Short Papers" will be given by Graduate Members, followed by discussion.

11th North-Eastern Graduate Section. A lecture will be given by J. M. Thirwell, Esq., Int.A.M.I.P.E., on "Production Planning and Control," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

11th Wolverhampton Section. A lecture will be given by Mr. R. Whibley, A.M.I.Mech.E., on "Unusual Grinding Operations," at the Wisemore Schools, Walsall, at 7-0 p.m.

12th Luton and District Section. A lecture will be given by C. Timms, Esq., M.Sc., A.M.I.Mech.E., on "Measurement of Surface Finish," at the Central Library, Luton, at 7-0 p.m.

12th Manchester Section. A visit has been arranged to Messrs. Ferranti, Ltd., Moston Works.

13th London Section. A lecture will be given by C. J. Whitcombe, Esq., on "Cold Forging" at the Institution of Mechnical Engineers, Storey's Gate, St. James's Park, S.W.1, at 6-30 p.m.

February Meetings—*Cont.*

15th Yorkshire Graduate Section. A lecture will be given by R. Cooper, Esq., A.C.C.A., A.I.I.A., on "Cost Control As An Aid to Management," at the Great Northern Hotel, Bradford, at 2-30 p.m.

17th Derby Sub-Section. A lecture will be given by Miss Shaw, M.A., M.I.P.E., on "Motion Study," at the Art School, Green Lane, Derby, at 6-45 p.m.

17th Halifax Section. A lecture will be given by Dr. J. W. Jenkin, on "The Manufacture of Seamless Steel Tubes," at Whiteley's Cafe, Westgate, Huddersfield, at 7-0 p.m.

19th North-Eastern Section. There will be a Discussion Night on "Apprentice Training," opened by W. A. Hildrew, B.Sc.(Eng.), A.M.I.Mech.E., M.I.P.E., M.I.Mar.E., and G. M. Baker, B.Sc., A.M.I.Mech.E., at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

19th Preston Section. A lecture will be given by A. C. McDonald, Esq., B.Sc., A.R.I.C., M.I.A.E., on "Modern Heat Treatment," at Messrs. Clayton, Goodfellow & Co., Ltd., Blackburn, at 7-15 p.m.

19th Sheffield Section. A lecture will be given by Messrs. J. F. Waight and J. Palser on "Furnaceless Heating by Town's Gas," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

19th Birmingham Section. A lecture will be given by Lieut. (E.) R. T. M. Toyn, R.N.V.R., M.I.P.E., A.M.I.Mech.E., M.I.B.F., on "Apprentice Training," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-0 p.m.

20th Glasgow Section. A lecture will be given by H. G. Houghton, Esq., on "The Application of Production Standards in Industry," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

20th Leicester and District Section. A lecture will be given by F. G. Rout, Esq., A.M.I.W., on "Fabrication Design as a Substitute for Castings," at a Joint Meeting with the Leicester Association of Engineers at the College of Technology, Leicester, at 7-0 p.m.

February Meetings—*Cont.*

21st Western Section. A lecture, illustrated by slides, will be given by S. Cosgrave, Esq., on "High Frequency Induction Heating," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

21st Manchester Graduate Section. A lecture will be given by L. P. Coombes, Esq., M.I.P.E., M.I.Mech.E., on "Motor Car Production."

22nd Birmingham Graduate Section. An afternoon visit has been arranged to Birmingham Industrial Research Laboratories.

26th Manchester Section. A lecture will be given by W. Symes, Esq., on "Function and Operations of Works Committees in the Engineering Industry," at the College of Technology, Manchester, at 7-15 p.m.

28th Halifax Graduate Section. A lecture will be given on "Powder Metallurgy" at the Technical College, Huddersfield, at 7-0 p.m.

28th Eastern Counties Section. There will be a discussion on "Relationship between Research and Production Engineering" at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

March Meetings

3rd Coventry Graduate Section. A lecture will be given on "The Production of Radar Equipment," at the Coventry Technical College, Coventry, at 7-15 p.m.

3rd Yorkshire Section. The Annual General Meeting will be held at the Hotel Metropole, Leeds, at 6-30 p.m., followed by an address by the President, R. Blackburn, Esq., O.B.E., M.I.P.E. M.I.Mech.E., A.M.I.C.E., F.R.Ae.S., on "The Early Days of Aviation."

6th Nottingham Section. A lecture will be given by Dr. S. Buchan on "Elastomeric Engineering," at the Victoria Station Hotel, Nottingham, at 7-0 p.m.

7th Yorkshire Graduate Section. The Annual General Meeting will be held at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

March Meetings—*Cont.*

7th Western Section. The Annual Section Meeting will be held at the Grand Hotel, Broad Street, Bristol, 1., at 6.45 p.m.

8th Yorkshire Graduate Section. A visit has been arranged to Messrs. Brook Motors, Ltd., Huddersfield, at 2.30 p.m.

11th Birmingham Graduate Section. A lecture will be given by A. E. Pickles, Esq., on "Production Heat Treatment Equipment," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-15 p.m.

11th North-Eastern Graduate Section. A lecture will be given by G. W. Robinson, Esq., Grad.I.Mech.E., Grad.I.P.E., on "Turbine Blade Production," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

12th Luton and District Section. A lecture will be given by W. Whitworth Taylor, Esq., on "Researches in High-Speed Carbide Milling," at the Central Library, Luton, at 7-0 p.m.

12th Wolverhampton Section. A lecture will be given by H. H. Beeny, Esq., M.Met. F.I.M., on "Cutting Lubricants and Coolants," at the Dudley and Staffordshire Technical College, Dudley, at 7.0 p.m.

17th North-Eastern Section. A lecture will be given by Dr. W. Wilson on "Electronics in Industry," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

17th Halifax Section. A lecture will be given by V. McWilliam Chandon, Int.A.M.I.P.E., on "Bright Electroplating and Electropolishing," at the White Swan Hotel, Halifax, at 7-0 p.m.

18th Wolverhampton Graduate Section. A lecture will be given by Dr. Yarsley on "Plastics," at the Wolverhampton Technical College, at 7-0 p.m.

19th Lincoln Sub-Section. A Joint Meeting with the Gainsborough Engineering Society has been arranged, at which a lecture on "Ball and Roller Bearings" will be given.

19th Preston Section. A lecture will be given by H. Eckersley, M.I.P.E., on "Recent Developments in Metal Cutting Technique," at the Harris Institute, Avenham, Preston.

March Meetings—*Cont.*

19th Birmingham Section. A lecture will be given by Messrs. W. Ogilvie, M.I.P.E., and S. Ackrill, A.M.I.P.E., on "Multi-Spindle Automatic Machines," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-0 p.m.

19th Sheffield Section. A lecture will be given by J. T. Lewis, Esq., on "Hydraulic Presses for the Hot Working of Metals," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

20th Leicester and District Section. A lecture will be given by L. W. Johnson, Esq., on "Metallurgical Factors Influencing Machinability" at the College of Technology, Leicester, at 7-0 p.m.

20th Glasgow Section. A lecture will be given by W. Harmer, Esq., on "Threading," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

20th Manchester Section. A lecture will be given by T. C. Parker, Esq., on "Cold Heading and Thread Rolling" (with film), at Liverpool University, Brownlow Hill, at 7-15 p.m.

21st Manchester Section. A lecture will be given by T. C. Parker, Esq., on "Cold Heading and Thread Rolling" (with film), at the Mechanics' Institute, Crewe, at 7-15 p.m.

21st Western Section. A lecture will be given by Lieut. (E) R.T.M. Toyn, R.N.V.R., M.I.P.E., A.M.I.Mech.E., M.I.B.F., on "Apprentice Training" (illustrated by slides) at the Grand Hotel, Broad Street, Bristol, 1., at 6.45 p.m.

24th Derby Sub-Section. There will be a meeting in the Art School, Green Lane, Derby, at 6-45 p.m., when a sound film, "Wheels Behind Wheels," will be shown.

26th Birmingham Graduate Section. There will be an afternoon visit to Highley Colliery underground workings, and an evening visit to the Dunlop Rubber Co. Ltd.

26th Manchester Section. A lecture will be given by F. J. Everest, M.Sc., A.M.I.Mech.E., A.M.I.E.E., on "Developments in Gear Cutting and Finishing Processes," at the College of Technology, Manchester, at 7.15 p.m.

March Meetings—*Cont.*

27th London Section. A lecture will be given by W. A. Hawkins, Esq., on "Precision Thread Rolling," at the Institution of Mechnical Engineers, Storey's Gate, St. James's Park, S.W.1, at 6-30 p.m.

28th Eastern Counties Section. There will be a meeting in the Lecture Hall, Electric House, Ipswich, at 7-15 p.m. when short papers on a Production Engineering subject will be given by Junior Members.

29th Yorkshire Graduate Section. A lecture will be given by Dr. E. C. Walton on "The Application of Electricity for Production," at the Great Northern Hotel, Leeds, at 2-30 p.m.

Obituary

We deeply regret to announce the deaths of Mr. R. Ardaillon, Int.A.M.I.P.E., of London Section, and Mr. Cecil G. Cornock, Int.A.M.I.P.E., of Western Section.

Formation of Calcutta Section

The recently formed Calcutta Section of the Institution of Production Engineers has taken shape rapidly, and their activities are now in full swing.

Meetings of the Temporary Working Committee are being held at monthly intervals, and two Sub-Committees have been formed for the purpose of dealing with the selection and recommendation of candidates for membership, and the selection and preparation of papers to be read to the Section.

The Temporary Working Committee is constituted as follows :

Dr. A. H. Pandya, Chairman.
Mr. J. D. Scaife, M.I.P.E. (acting *ex-officio*).
Mr. T. R. Gupta, M.I.P.E.
Mr. R. L. Kapoor, A.M.I.P.E.
Mr. T. B. Gray.
Mr. D. Williams, Grad.I.P.E.
Mr. J. L. Halmshaw, Int.A.M.I.P.E.
Mr. N. G. Chakrabarti.
Mr. J. B. Ghosal.
Mr. E. H. Y. Burden, Acting Hon. Secretary.

The Paper Sub-Committee consists of Mr. R. L. Kapoor, A.M.I.P.E., Mr. J. L. Halmshaw, Int.A.M.I.P.E., Mr. D. Williams, Grad.I.P.E., Mr. J. D. Scaife, M.I.P.E. (acting in an advisory capacity), and Mr. E. H. Y. Burden, Acting Hon. Secretary.

The Membership Selection Sub-Committee will consist of Mr. T. B. Gray, Mr. T. R. Gupta, A.M.I.P.E., Mr. J. D. Scaife, M.I.P.E. (acting in an advisory capacity), and Mr. E. H. Y. Burden, Acting Hon. Secretary.

Applications for membership are being received, and after scrutiny by the Membership Sub-Committee those selected will be forwarded to London for consideration.

The Paper Sub-Committee is at present dealing with the question of papers to be read to the Section, and it has been agreed to act on Mr. Scaife's suggestion that for the first two or three meetings papers should be taken from the Institution's Journal.

The first full meeting was held during the first week in January, and was well attended, notifications being sent to all prominent engineers in the Calcutta area, irrespective of whether they are members of the Institution or not.

The first paper to be read was in the form of condensed extracts from five papers which have appeared in the Journal, dealing mainly with the Functions and Aims of Production Engineers, as follows:

1. Production Control for Widely Varying Products.
2. Methods and Problems of Factory Control.
3. The Outlook for the Production Engineer.
4. The Organization of Production Engineering.
5. Functions of a Planning Department, as applied to an Instrument Factory.

Several members are at work on the preparation of their own papers, which will be read in due course at subsequent Section Meetings.

Issue of Journal to New Members

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

Important

In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

THE IMPORTANCE OF STANDARDISATION

by J. E. BATY, M.I.P.E.

Chairman of the Standards Committee, Institution of Production Engineers.

It is seldom realized by engineers, or industrialists generally, how much standardisation enters into our economic life. Many examples might be cited, but to mention only one—all pipes for gas, water or steam are screwed to B.S. Pipe Thread Specification and pipes and fittings are interchangeable throughout the British Isles. Not only that, but B.S. Pipe Thread is used in almost every country in the world, except North America. It is due to the foresight of British Engineers in 1902 that we have this almost universal standard ; and of course to Sir Joseph Whitworth for establishing the thread form over 100 years ago.

Very little reflection will convince one of the economies which may be effected by wise standardisation. Before a British Standard is published it has to be agreed between producer and consumer, and it receives a very wide criticism by all interested parties. It must not be such that it restricts progress in design and it must be revised periodically to keep abreast of any advances made in industry.

Between the standardising bodies of the various countries of the British Commonwealth there exists a very close link ; in many cases British Standards are adopted by Overseas Standards Associations with little or no alteration. Furthermore, the United Nations countries are getting together with a view to co-ordinating standards wherever possible.

Standardisation is of two kinds, functional and dimensional.

Functional standardisation deals with fitness for purpose and implies the setting up of a standard to which conformity is desirable. It may cover any of the following fields :—

Terms and Definitions : to secure accuracy of description.

Quality : to assess fitness of purpose.

Methods of tests and methods of sampling.

Methods of use (*Codes of practice*) : to define the correct application of materials or appliances.

Dimensional standardisation is carried out to achieve simplification, unification and interchangeability. By eliminating any unnecessary multiplicity of sizes or types of articles and appliances, such standards facilitate the processes of manufacture and replacement of parts and reduce makers' and distributors' stocks.

The British Standards Institution was founded in 1901 and incorporated by Royal Charter in 1924. The Institution is governed by a General Council, whose members are widely representative of government departments, professional institutions and industrial and trade interests. Under the General Council are four Divisional Councils: Building, Chemical, Engineering and Textile. Each division is divided into Industry Committees, of which there are 38. Over 1,000 Technical and Sub-Committees, set up by the Industry Committees, are entrusted with the drafting of specifications. The distribution of the Institution's 1,500 British Standards amounts to over half a million annually.

A number of members of the I.P.E. serve on British Standards Committees, but this representation could be increased with advantage to our Institution and to the engineering industry, as specialised knowledge is frequently sought. All Members and Associate Members will by now have received a copy of the Head Office letter requesting their co-operation in this respect, and if those who have not already done so will return their completed questionnaire to Headquarters, they will greatly help the work of the I.P.E. Standards Committee, who are looking after their interests in standardisation.

One other point, if you see the need for standardisation in any section of your work, write to Headquarters about it. The matter will receive consideration and if approved, a request will be made to B.S.I. to undertake the work.

LOOKING BOTH WAYS

by SIR CLAUDE GIBB, C.B.E., F.R.S., M.I.Mech.E., M.I.P.E.

Presidential Address to the North-Eastern Section of the Institution of Production Engineers, December 12th, 1946.

I would first wish to pay tribute to my predecessor, Mr. Charles Noble. His unflagging interest in the affairs of the North-Eastern Section of our Institution and the wisdom he brought to our meetings call for more than the usual thanks which we extend to retiring Presidents. I would ask Mr. Noble to accept your thanks and very deep appreciation for his leadership, and to express the hope that he will long continue to maintain interest in the work of this section.

Next, I would like to express my own appreciation of the honour which election as your President confers. I hope during the course of this address to give you some of the reasons that I see for continual striving to maintain a strong Institution of Production Engineers, with its activities always kept at the highest possible pitch.

Selecting a title for a Presidential Address is almost more difficult than selecting a subject ; but when a title is selected such as " Looking Both Ways," the subject becomes quite easy, because under the broad scope of that title one is at liberty to roam forwards as well as backwards and to pause in the present to look at the many problems around us.

Great Britain has just emerged from a disastrous second World War, and we to-day are struggling—and I am not quite sure that the correct word should not be floundering—in the aftermath of that war. True peace has not yet been achieved, and there are many who think that world peace is further off to-day than it was in May, 1945, when victory in Europe was proclaimed. Certain it is that in many respects the ordinary citizens of Great Britain are at least as badly off for the ordinary commodities of life as they were at the peak of the war.

It is of interest to study the proportion of national income spent for direct war purposes over six years. The United Kingdom spent 44 per cent. of her total national income for direct war purposes over six years of war. Russia spent 37 per cent. ; Canada 33 per cent. ; New Zealand 31 per cent. ; Australia 29 per cent. ; and the United States of America 24 per cent. These are most enlightening figures and give some indication of the problem facing this country in re-establishing its own internal economy.

That, however, is only part of the story. The sale of British investments abroad—particularly in the U.S.A., before Lend-Lease—

has reduced our national income by a very large sum. At first sight, the amount of the American loan to Britain seems huge, but that loan is put into its true perspective when we know that the amount is only half the cost of repairing the bomb damage in Great Britain.

This country is in a mess and the sooner we admit the fact and face up to realities, the sooner we will get out of it.

If there is one thing on which politicians of all parties, economists and business men universally agree, it is the vital necessity for this country to export on a scale never previously reached. The reason is fairly obvious—we must import so much of our food, so much of our raw materials—and with our interests from overseas investments and our shipping earnings seriously reduced, exports must increase to pay for our imports. The experts will enlarge on these reasons and make the maximum mystery of what is really simple arithmetic, and a very ancient rule that " You can't get something for nowt."

Another thing on which most politicians, economists and business men agree is that the output per man-hour to-day is lower than it was pre-1939, and much lower than during the late war. The reasons given for this vary according to one's political, economic or medical outlook. It is said that men worked so hard and for so long under the stimulus of war that they are tired and stale to-day. That the shortage of food with its monotony and low nutritive value has sapped our energy. That taxation—particularly Pay As You Earn—has reduced incentive in those men who by hard work could earn big money. That the shortage of consumer goods in the shops and the fact that there is little on which to spend money has again reduced incentive.

All the talk I have heard or seen in print has been of the lost incentive or output of the actual producer—the workman. No mention of lost incentive in management—not a word of the managers who might also be expected to be tired and stale, to be suffering from malnutrition, to be fed up with high taxation. Yet it is evident to anyone looking for those signs that they are there, and in large measure.

Just as many workmen say or think " Why should we work hard," or " Why shouldn't we take a day off when we want to," so far too many executives are acting as though they were thinking " Why should I sweat to keep costs down—the Government will take my profits in one way or another," or " This is a seller's market and I can sell everything I can make," or " Only a slump—which must come soon—will make my men and my material suppliers be sensible in giving a reasonable return for my money."

Nothing could be more dangerous than management fatigue, and I want to give you something on which to think. From

September, 1933, to September, 1946, works costs of electrical generating plant increased 120 per cent., and this despite great advances in manufacturing methods which prevented the increase being even higher. Costs are still rising in this country—materials are going up at a rate alarming to anyone exporting a large proportion of total production. Wage increases are by no means ended and in general, up and down the country there is little sign of response to the many appeals for greater output and increased production. Most people pay lip service to these appeals but nothing really happens.

You gentlemen may say there is nothing you can do about it, but if—as appears to be the case—everybody takes that delightfully easy line, then we shall certainly sink deeper into the mess we are already in. There *is* something you can do about it. The members of this Institution are—in the main—responsible for planning or supervising actual production and therefore are in touch with both workpeople and senior management. You—by your example—by clear thinking—and by blunt talking in and out of business hours—can exercise an influence far greater than you imagine. Unless somebody starts off in the right direction, there will be nobody for the masses to follow. I really believe the members of this Institution can do a tremendous amount to start the upward movement, and there is nothing more important for Great Britain *and* the world than that we should regain our industrial leadership.

What is really wrong with us ? Are we tired and stale ? I have been averaging over 90 hours a week on the job for over seven years and still am. Yes, we probably are tired and stale, but not more so than we were in 1940 and 1941 when we were fighting for our very lives. If we have not the stimulus to work to-day, then it is because we do not realize how desperate is our position to-day. The problem has not been put across, and you gentlemen can spread the Gospel of Hard Work and why it is necessary.

Are we undernourished and soured by the monotony of our food ? I have recently been in Australia, where the food was so good that I honestly could not remember whether in pre-1939 we ever reached its excellence in this country. The variety, quality, and quantity of food in Australia are superb—yet no one wants to work there any more than here. Certain it is that food cannot be blamed in Australia for the industrial unrest and " go slow " that is so evident there.

Is it taxation or P.A.Y.E. destroying incentive ? If so, again the problem has not been put over and again you can help. Somebody—or rather everybody—has got to pay for the luxury of a war —must pay for improved social services—must pay for all the many things a benevolent government does for us these days. Again we must realize " You can't get something for nowt." Of course

we want, and should have, social security, better education, better housing, and all the many things we are promised, but they have to be paid for.

The British people did not flinch when Winston Churchill told them blunt truths and bitter facts. The British working man is no fool and is not a coward, but if he doesn't know the reason for things, he can be damned pigheaded.

Does the lack of goods in the shops really affect a man's output? If so, is there anything that can be done about it? I believe there is. There are two things only you can do with money—spend it or save it. If you can't spend it, but had been given attractive and sensible reasons for saving, then you wouldn't mind if you couldn't spend it. But why should you save it? There is no shortage of jobs, and if your present one flops you can easily get another one. If your boss doesn't think you are working hard enough—in other words, you are not producing enough—and sacks you, there is no need to have saved because there are plenty of other jobs and there is always the dole. There is no need to save for old age—the new social insurance scheme provides for your old age. There is no need to save to buy your own house—the national policy is to force people to rent state or municipal owned houses. If you don't own a thing, your pride in it is reduced or eliminated, and you don't want to spend (and therefore to save) money for making your home attractive.

Are we at last coming to the root cause of low output—a reduction of pride? Less pride in our homes, less pride in our products of manufacture, less pride in our country. Or is it that the fear of unemployment, the fear of old age, has gone and that fear as a spur no longer exists? Both are horrible thoughts, and I find it hard to believe that pride cannot be restored or that fear is necessary for any Britisher to give his employer a fair return for a fair day's pay.

But you, gentlemen, no less than Ministers of the Crown, must search for the truth and then for the remedy of these problems.

The Chancellor of the Exchequer recently gave the value of one pound sterling to-day as 49 per cent. of the value in 1914. Our "quid" is now worth less than ten "bob." When I went to buy a new hat some time ago, I felt quite sure the Chancellor was very much out in his figures, and the value was nearer 20 per cent.

My company have adequate export orders for electrical generating plant, but a recent example of competition is an indication of the shape of things to come. Tendering for a turbo-alternator to a European country which is a food exporter, my company's price of £123,000 was the lowest British price and lower than Swiss and Swedish tenders, but the order was placed with Czecho-Slovakia at £68,000. Obviously that company wanted work badly, but we also wanted that order and had quoted a cut price. Can the

Czecho-Slovak company cover their costs at that low price? I believe they can—their coal and steel costs were half ours pre-war, and their workmen are highly skilled and industrious. I give that example as a taste of the competition coming before long when the present sellers' market ends.

I do not want to be a dismal prophet, but I do want to look at facts squarely, and to know the truth.

I make no attempt to put forward a solution to the problems of to-day—to submit plans for the future—already we see a huge superstructure of planners being superimposed on our actual producing force and those planners must be paid from *our* production. Never let us lose sight of the fact that anyone who is not actually producing (and that includes, I imagine, everyone of us in this room) must be supported by those who do. The managing director or chief executive, without whose foresight and planning production could not go on, no less than the office boy, must take his salary out of the earnings made possible by the men who actually make the articles which are sold. The fact that the producer is useless without the executive or the executive without the producer is something the whole nation and its leaders must always remember. It may be easier to replace the producer than the executive because it takes longer to train and provide the necessary experience for the executive, but he and the producer are equally necessary.

Until there is not only a realization of the necessity for teamwork, but there is built up the team spirit, industry—whether in Britain or any other part of the world—will not reach the necessary efficiency to hold its own. You, gentlemen, can help foster the team spirit in illustrating the interdependence of one section of a works with another. You may be inclined to think that without your planning of production, without your designing of the tools of production, there could be no production. This is so. Yet you, like any other section of the production team, must not think you could do anything without the other members of your team, and you must never lose sight of the fact that your salaries also are paid from the actual earnings of the man at the machine—the man who makes the casting or forging—the man who wins the iron ore or he who mines the coal. All are units in the production chain which could not go on with any one unit missing or out of step.

It is incumbent upon every one of us to ensure that we are not being extravagant in any phase of production activity. It is just as wrong to over-tool a production job as to under-tool it. Just as wrong to have two office boys when one would do as to carry passengers or dead wood amongst the senior executives. Economy and efficiency must be the watchwords of our country if we are to climb out of the mess we are now in.

In the seller's market which exists to-day, the prime consideration must be efficient design and production. But in a few years time, when a buyer's market may well be with us, there is in addition to design and production the important aspects of selling. We should be training to-day for the buyer's market ahead, and for this, world events in the past few years have demonstrated so emphatically what poor showmen are the British as a race. We are all familiar with Radar, and because Radar has an American title are inclined to believe, as the Americans do, that Radar was conceived and invented in their country. But Radio Direction Finding, or R.D.F. as it was known in the earlier days, preceded Radar, and the true credit for leading the world in that field should be given to our own scientists.

In atomic research, Thompson and Rutherford led the world, and although the gigantic resources of America, with their freedom from bombing, made it expedient for the ultimate development of the atomic bomb to be carried out in America, yet again it is to the scientists of this country that the true credit is due. The sulpha drugs and penicillin, which saved thousands of lives in the armed forces of the Allied Nations, owed their existence to the researches of British medical scientists.

" Mulberry," " Pluto," " Fido," " D.D."—all of which are now household names—were conceived, designed and manufactured in Great Britain under the stress of war and played a greater part in final victory than has ever been acknowledged or even claimed by Great Britain. Without " Mulberry," we could not have maintained our shock troops on the beaches of Normandy over the first critical weeks of invasion. Without " Pluto," it is quite certain we could not have maintained our armoured forces and our mechanised army in the chase across Europe without fantastic losses of tankers and their crews. Without " Fido," our losses of returning bombers under fog and low cloud conditions would have been much higher than they were. Without " D.D."—the swimming tank—it is problematical whether our attack on Normandy would have been the success it was, or whether the crossing of the Rhine could have been accomplished so apparently easily.

I do not suggest—indeed, I would hate—that we as a nation should think we are the inventors of everything in the world, or that we have built the biggest of this, the largest of that, or the greatest of the other thing. But, looking ahead to our phantom buyer's market, this country must assert itself and see that its scientists, engineers and craftsmen are given the credit for their skill, their experience, and their initiative.

I cannot glance through the advertisement pages of an American magazine or an American journal without feeling that I want to buy a large number of the things which are depicted so attractively.

And I have the urge to buy these things despite the fact that my knowledge and experience of American goods has convinced me quite clearly that there are British equivalents at least as good and probably much better. I am not decrying America with its huge production and huge internal domestic market, but I am trying to make you gentlemen think as to whether this country has not, is not, and cannot do as well and better.

Great Britain has suffered in her internal economy and the standard of living of her people as much or more than any other country amongst the allied nations. I say this even after considering Russian losses and damage. It is natural that under present post-war conditions there should be a slight feeling of inferiority complex. But we must snap out of that. We do not want to adopt the Hitler slogan of "The Master Race," but we do want to remember that ancient Simian proverb "What one fool can do any other fool also can do." We do want to remember that the way to obtain maximum progress is for every man jack of us to have as his aim and ambition to be efficient in the job allotted to him no matter what that job at the moment may be.

It is a good thing occasionally—but not too often—to stand still and look both ways. To look back at the past and see the mistakes we have made. Not so that we may despair over past mistakes, but that we may analyse why we made those mistakes and then look confidently to the future, knowing that we shall not again repeat those past mistakes, although we can be sure we shall make new ones in our endeavours to move forward. You may feel, gentlemen, that this talk is full of platitudes. I think perhaps it is. But I am now old enough to know that whereas thirty years ago my opinion of current engineering practice was not terribly high, I now know that grandfather was a damned good engineer. I now know that in the great majority of cases we can learn more and can progress faster if we look back and study past experience before embarking on some new venture which may take us into the realms of the unknown.

There is an ancient Japanese proverb which I know many of our successful commanders in the South-East Asia theatre always remembered. It is "He steps back to jump the further." It is a proverb well worth remembering when faced with some new problem. Sir Charles Parsons often advised the younger members of his staff in this way: "If, in your development, you come to a stone wall, do not try to batter your head through it. There is always a way over the top or underneath or around the ends of it." On another occasion he said, "If your development has been carried out step by step and always properly analysed, then when you come to a big jump into the unknown, courage and your earlier work will take you safely over."

It is customary for a President to speak on some subject of which he has special knowledge, and to follow that tradition, I should have talked to you on turbo-alternators. Turbo-alternators have probably contributed more to higher standards of living than almost any other development since the original steam engine, or going back very much farther, the invention of the wheel. It is a fact that those countries having the highest standards of living are those employing the greatest amount of electricity per head of population. Electricity as our servant is much more valuable in improving the amenities of life than the aeroplane, the wireless, or any other of our modern aids to life. The rapid extension of the uses of electricity is due to the greater efficiency in production which it made possible.

It is unlikely that even should atomic energy become available to us within our lifetime, there would be a reduction in the cost of electrical power generation, or that electricity would be more widespread in its availability than our present methods of generation and distribution can provide when fully developed. If we are to make further industrial progress, it must come through the more efficient utilisation of power. Power must be harnessed much more widely to the use of man, and in that way bring greater output per man per hour and thereby a greater efficiency of production.

If we pause and look back over the field of electrical generation, we see that in the past fifty years the amount of coal required to produce one unit of electricity has been reduced from about 5 lbs. to under 1 lb. Considering the present, however, we find the law of diminishing returns applying and the scope for improvement in the future is relatively small. It is indeed unlikely that improvements in efficiency of electrical generation in the future will even balance the increases in fuel costs which seem likely to arise.

There are some who believe that the gas turbine will open up a new era of power generation. Those most competent to judge do not agree with that view but feel that the gas turbine will have its application in special fields, not seriously competing with the steam turbine. That there is a great future in front of the gas turbine is quite certain, but it will be much more complementary to the steam turbine than in substitution for it.

To look into the future of power generation—we see the solution to the many problems involved lying almost entirely in metallurgy. Twenty years ago, 750° F. was high for the total steam temperature at the inlet to a turbine. To-day, that figure has reached 950° F. This advance has been made possible by improvements in metallurgy and in the development and greater use of alloy steels. The long life gas turbine demands a temperature at least of 1150° F., and the indications are that a steel alloy can be used for such temperature conditions.

To make full use of the potential cycle of the gas turbine, temperatures of 1500° F. are essential, and to obtain long life, *i.e.*, a minimum of 100,000 hours of operation, new materials will be required, and it may well be that these materials will not be fundamentally of steel. Once recourse has to be made to non-steel based alloys, costs of materials become so high that the economics of the gas turbine begin to suffer and therefore the field of application becomes restricted.

The number of basic elements already known to scientists to-day is such that there is little hope of any new element being isolated which can be obtained in quantities sufficient to be commercially applicable. It is, of course, not beyond the bounds of possibility that the alloying effect of some hitherto unknown element may change the metallurgy of steel and make possible the higher temperatures and therefore the higher efficiencies of the gas turbine. But, if we are to be realistic, we must admit that whilst such discoveries are possible, they are distinctly improbable.

Whilst not ceasing in our search for improved materials, we should base our future production plans on the assumption that it is unlikely there will be any appreciable reduction in power costs.

The problem of the utilisation of atomic energy again is bound up with metallurgical solutions. New materials are required before atomic energy can have other than a very limited application.

How then can we obtain lower costs of production of both capital and consumer goods when the cost of power generation is unlikely to be reduced? It can be done by making more horse-power the servant of each producer. By building machine tools and mechanisms which will produce more articles per hour per man employed than hitherto—and this in the main means the removal of more material per hour from each machine. Heavier cuts or faster cutting speeds or faster feeds, or a combination of them all is the direction in which we must go; and for all of these advances machine tools will require to be stronger, more rigid and with greater power built into them.

So much has already been done on these lines that—as with the steam turbine—we are moving along the flattened part of the curve, where for every advance made the return we obtain is relatively smaller.

If there is not very much left to be obtained from the most modern machine tools or equipment, how then are we to achieve the necessary increased production and reduced costs? It is my belief that a great contribution can be made by the members of this Institution. Until a machine tool is operating and cutting—and therefore producing—100 per cent. of its running time, we have not achieved the ideal. A time study of most machine tools will reveal just how far from that ideal we are to-day. I know of one

case, that of a large radial drill, where the actual cutting time was only 8 per cent. of the total shift time. By careful re-planning and the provision of two beds for the one machine, that 8 per cent. was increased to 22 per cent. The members of this Institution do not need to be told that floor to floor times are the only criterion. It is your job as the production engineer to study and strive to reduce setting times, to reduce waiting and dead time until floor to floor times are really a minimum. It is also your job to guide the designer so that the products are capable of easy setting and require the minimum of machining.

You will say that all this is commonplace, that it is your daily job by which you earn your bread and butter. But the purpose of this talk is not to attempt to tell you anything new, but to make you think—to make you realize that we are in a mess to-day, and that only by re-examining at frequent intervals the production processes for which you are responsible will it be possible for you to see where still further economies can be made. In short, gentlemen, I am trying to give you the incentive for greater efforts.

Once you have achieved the maximum production from a machine tool—once you have achieved the minimum setting time for a particular component—then you must play your part in ensuring that the operator operates the machine to its maximum capacity. For that to be attained, there must again be some incentive. It is my belief that that incentive can only come from some form of output bonus plus a restoration of the pride of craftsmanship, which appears to have lessened in recent years and to-day is at a low ebb. There is no general rule which can be given for the restoration of that pride. It depends so much on the traditions of the factory and on the confidence between management and workpeople.

There is one way which can at least start a pride in the factory or the company by whom the operator is employed, and that is to give outstandingly bright, cheerful and clean conditions of employment, particularly in the North, where our workshops have too long been too drab. The traditional colours in which machine tools are painted certainly are utilitarian in that if oil is spilled or leaks, it does not show up as a sharp contrast. For too long have we put up with girders, steel frames and brickwork which have the accumulation of years of dust and soot from our dirty atmosphere and from the operations performed in the shops. Totally inadequate attention to light—both daylight and artificial—has been given and the overall result is a drabness which is not only depressing but extremely inefficient.

During the late war, it was necessary to build a large number of new factories, some controlled by Government departments, such as the Royal Ordnance Factories, and many others as extensions to existing works. Those new factories were frequently given their

initial coat of paint in colours much lighter than the traditional workshop painting. In some factories even the machine tools were painted more cheerfully than the battleship grey which has been our standard for too long. Where those brighter colours were adopted, it seemed that the outlook of the workpeople was more cheerful, but it is not possible to generalize on those war factories because often the executives responsible for their operation also were responsible for the colour selected for painting buildings and machines, and those who selected the more cheerful colours themselves had an enlightened attitude towards production. It is difficult, therefore, to decide whether the greater output from those cheerful factories was due to the effect of colour or to the effect of good management.

In the United States of America a very large paint manufacturing company has conducted intensive propaganda in the use of colour in factories, and have called the study of colour in the pamphlets they have issued describing it "Colour Dynamics." Being rather sceptical and yet attracted by American advertisements and salesmanship, my first reaction was that this was an admirable method of extending the sale of their paints. But a study of the psychological arguments put forward in support of their claims made one feel there might well be something worthwhile in it.

The shortage of paints to-day in this country is such that it has not been possible to test out these various colour schemes on other than a limited scale, but already in our works we have done sufficient to feel sure that there is a great deal in colour psychology. Already our workpeople have expressed appreciation for the greater cleanliness and the more cheerful surroundings in which they work. We have yet to inculcate the spirit of personal cleanliness and machine cleanliness, but that will come.

In past days, when pride of craftsmanship was very strong, drab surroundings did not appear to reduce that pride. To-day, I am certain that if factory surroundings are depressing, the mental approach of the man to his job will be slack—he will come to work merely to fill in sufficient hours to make sure that his pay packet materializes at the end of the week—he will not work at maximum speed or at maximum efficiency—he will not consciously attempt to earn the biggest pay packet of which he is capable.

If he works in dirty surroundings, he is more than likely to go home dirty and to remain dirty. He will not have a pride in a clean, colourful and cheerful home, and because he lacks that pride in his home, he will lack pride in his work. If he is given workshop conditions more cheerful, more colourful and cleaner than his home, it is almost certain that the contrast between workshop and home will stimulate a desire to make the home brighter, and once that process is begun it will become cumulative and there will be pride

in home, in workshop and in the machine or equipment for which he is responsible whilst working. That in itself will induce the desire to keep his equipment clean and quite unconsciously his whole approach—not only to work but to life itself—will be changed, and changed for the better.

For maximum efficiency in production the fitting together of many machined components must become a matter of pure assembly, with a complete absence of handwork on any component. That ideal cannot be achieved merely by installing the best machining equipment, because, except in a quite limited sphere of manufacture which is rarely found in the north-east, large-scale production where the operator cannot make a mistake does not exist. The finest machine tool is of little use unless the operator has both the will and the skill to use it to its limit. Accuracy can be improved by stimulating the operator so that he consciously wants to produce a job as near perfection as possible. Accuracy will not be achieved or maintained if there is a "don't care" mental attitude on the part of the man.

Colour can, I am sure, play a part in that mental stimulation, and in restoring the lacking pride of craftsmanship of which we were once so proud.

The sceptics say that unless the painting is kept clean and is renewed frequently, it quickly will look tawdry and cheap. My reply to that is that the cost of keeping clean and the cost of more frequent repainting will be more than balanced by the increased production and the improved mental outlook of the operators.

Such a scheme, however, can only be the first move in the building up of pride and the desire to work. Confidence between workpeople and management is vital, but is extremely difficult to obtain. Let us face facts and say quite bluntly that there have been many cases in the past where management has been bad and workpeople treated with little or no more consideration than had they been machine tools. In those factories, a bitterness has grown over the years and fear has been the dominant incentive to work—fear of unemployment, fear of starvation. This has been swept away almost overnight by a shortage of labour and the introduction of social services undreamed of thirty years ago. There are plenty of factories where for generations there has been reasonable consideration of the welfare of the workpeople and where there has been close touch between what used to be called "master and man."

Those factories were in the main relatively small, and where the master had either started the business himself or was the son or the grandson of the founder. In those factories it was not only commonplace, but almost accepted, that the son of a workman should enter the factory as soon as he was old enough, and there was a family tie and a family spirit, not only in management, but

amongst the workpeople in those factories—and here the word "factories" is being used in the widest sense to include all forms of industrial activity. There had been developed a pride of craftsmanship which provided all the necessary incentive to high output and high quality.

The impact of war production on all factories was very great. Those that had a good spirit were either depleted of staff or had greatly increased numbers of workpeople directed to them, depending upon their peace-time product and whether it was required for war. Labour turnover in all factories was very high and a large proportion of pre-war workpeople had been changed for one reason or other by the time we reached 1946. Thus, in many factories, the traditions of the past have been broken and there is hardly a factory throughout the whole country that has not had to look at the relationship between workpeople and management in an entirely different light to that ruling pre-war.

Workpeople who were embittered by some experience of their own in pre-war days frequently are voluble in recounting their own experience to otherwise satisfied men, and distrust quickly is spread amongst the whole factory by a few new starters. The best management in the world can be upset and brought under suspicion by a relatively few dissatisfied men. Human nature being what it is, there will always be some who have a grievance which is just as likely to be imaginary as real. But these men are potential sources of unrest in any factory. It is believed that the only way to handle them is so to strengthen the outlook of the reasonable men—who form the great majority but who generally are inarticulate—that they *do* stand up and, in effect, tell the discontents to "shut up." In this talk I am not attempting to offer solutions, but, as stated earlier, attempting to make you gentlemen think. I shall not, therefore, pursue further this question of relationship between workpeople and management, but leave it to you to study the atmosphere in your own particular works.

Having one further and final look into the future, we should examine the supply of craftsmen and operators for manning our factories over the next ten, twenty and thirty years. It is generally accepted that the exports of this country—once the present seller's market has faded into a delightful memory and we live in the harshness of a buyer's market—will consist almost entirely of capital and super-quality goods. Consumer goods of everyday quality will in future be manufactured in the countries to which we exported pre-war, and to which we may be exporting at this moment. Australia, Canada, South Africa, India, have already proved that they are quite as capable of producing articles of everyday use which form such a large part of our exports to-day at least as economically as this country. Considerations of national defence

make it incumbent upon those overseas countries to build up their secondary industries so that in the event of another war they will at least have some war-potential by which they can manufacture their weapons of defence. It is now part of the national policy of those countries to increase their war-potential, and it is essential for the defence of the Empire that this should be the case.

What, then, will be left to meet the increased demands for export which have been stated so forcibly by the President of the Board of Trade and the Chancellor of the Exchequer? It will be in the "one-off" articles or in those articles for which there is a very limited demand, or of a type demanding production equipment which has little use as war-potential. In the main, they will be capital goods and goods of outstanding quality amounting almost to luxuries.

How are we to prepare for the designing and manufacturing of that class of goods? Only by the building up of much higher standards of technical design, much higher standards of production methods, and much higher standards of craftsmanship in our workshops, mills, and factories generally. To do this, there must be higher standards of technical and general education, and much more attention to craftsmanship training than ever in the past.

Gentlemen, I close this talk on this note. If I have given you food for thought in ranging so loosely over so many subjects, my object will have been achieved. I repeat that it is to the members of this Institution probably more than any other walk of life that the first upward movement can take place, and that you can wield an influence far greater than you know amongst both workpeople and management.

PRODUCTION OF BEVEL GEARS

By G. W. NASH, Esq.*

Presented to the London Section, Institution of Production Engineers, 19th December, 1946.

A great deal has been written on the subject of gears, and many fine text-books containing lengthy formulae and beautiful tables of calculations prepared for simplifying the tedious work of gear design. The authors of these books have done a very fine job of work, and the help given to those responsible for the production of gears in having all this information available must be, and is, I am sure, acknowledged.

With all this information at hand, it is still considered by many that the production of gears is a real headache, and should be avoided.

When I was asked by your Secretary to prepare a paper on this subject, I was undecided on how best to set about the job. I came to the conclusion that there was no point in preparing a paper containing explanations and details of formulae, since they are already available in the many text-books to which I have referred. I do feel, however, that even now and with the extensive knowledge of production we have gained in the past few years, there are still many who do not appreciate the fundamental principles of good bevel gear production.

In 1874, William Gleason invented the first practical machine for cutting the teeth in bevel gears. During the two decades following the advent of this machine, which was of the planer type, there was a steadily increasing demand for cut bevel gears. For example, the chainless bicycle, which required a bevel gear drive, provided a market.

The early 1900's witnessed the birth of a new age—the age of mechanized transportation. Man's desire for better and faster means of travel found expression in the inventions of the automobile and the airplane. A new world was coming into being—a motive world in which bevel gears and bevel gear machinery were destined to play a vital role.

The development of new machines advanced the art of bevel gear manufacture, and, searching for better means of driving the wheels of automobiles, engineers logically turned to bevel gears, thereby creating new problems in bevel gear machine design.

In 1905, James E. Gleason developed what is known as the two-tool bevel gear generator. Not only did this machine produce

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gears in half the time previously required, but a better finish and smoother rolling were obtained.

A practical method of insuring proper operation of bevel gears in their final mountings was introduced in 1908, when the first Gleason Bevel Gear Tester was announced. This machine made it possible to give the gears a running test under power, simulating actual operating conditions, but before installation of the gears in their final mountings.

The expanding uses of bevel gears created a demand for still higher quality. The answer was found in the development of spiral bevel gears. In 1913, a process and tool for cutting the teeth of spiral bevel gears, which made such gears commercially practicable for the first time, was discovered and perfected by James E. Gleason. A machine to carry out the new process was designed by Arthur L. Stewart, his chief engineer.

The qualities of spiral bevel gears caused them to supplant straight bevel gears in the final drive of almost all motor cars and in many other drives where high speed and freedom from noise were characteristic requirements. From 1912 to 1925, a number of additional machines were developed for bevel gear manufacture, and included a high speed differential gear and pinion finishing machine, a quenching press for the controlled hardening of bevel gears, mass-production roughing machines for spiral bevel gears and pinions, an automatic burnishing machine for bevel pinions, an automatic lapping machine for spiral bevel gears and pinions, the first machine for grinding the teeth of spiral bevel gears and pinions, and a large amount of equipment for making and sharpening the cutters and tools employed on the cutting machines. Each of these developments contributed in some degree to the betterment of bevel gear manufacture.

Another revolutionary gear development was pioneered in 1925, when the chief mathematician of the Gleason Works, Ernest Wildhaber, invented a practical method for the manufacture of hypoid gears. Since in hypoid gears the axis of the pinion was offset from the axis of the gear, it was now possible to have continuous drive designs in which the driving shafts passed one another, and such gears found wide application in industry.

Of prime importance was the fact that the automobile industry, through the utilisation of hypoid gears for the rear axle drive, gained a great advantage and improvement in motor-car design and performance.

Types of Bevel Gears.

Before discussing the methods of producing the teeth and the machines and tooling used, it may be pertinent at this point to

describe briefly the various types of bevel gears in common use, their application, type of tooth bearing, and other general characteristics.

Straight bevel gears are the simplest form of bevel gears. They have straight teeth which if extended inward would intersect at the axis of the gear. Their use is generally limited to drives which

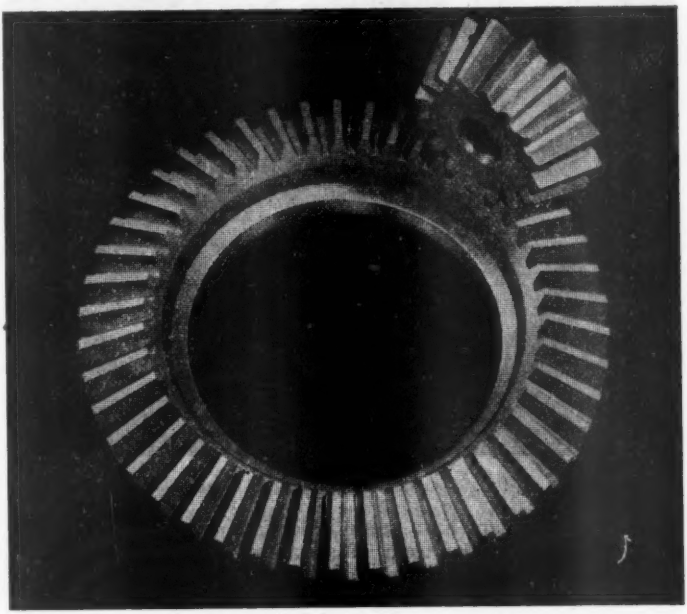


FIG. 1. Generated Straight Bevel Gears.

operate at relatively slow speeds. While it is not possible to establish an absolute maximum in terms of feet per minute beyond which straight bevel gears should not be used, it is generally recommended that spiral bevels be used when the speeds are in excess of approximately 1,000 surface feet per minute, or in the case of very small gears, 1,000 r.p.m. Obviously there are many factors which affect these values, the most important of which are smoothness and quietness, load carrying capacity, mounting conditions, accuracy in the manufacture of the gears and housings, and accuracy in assembly of the gears.

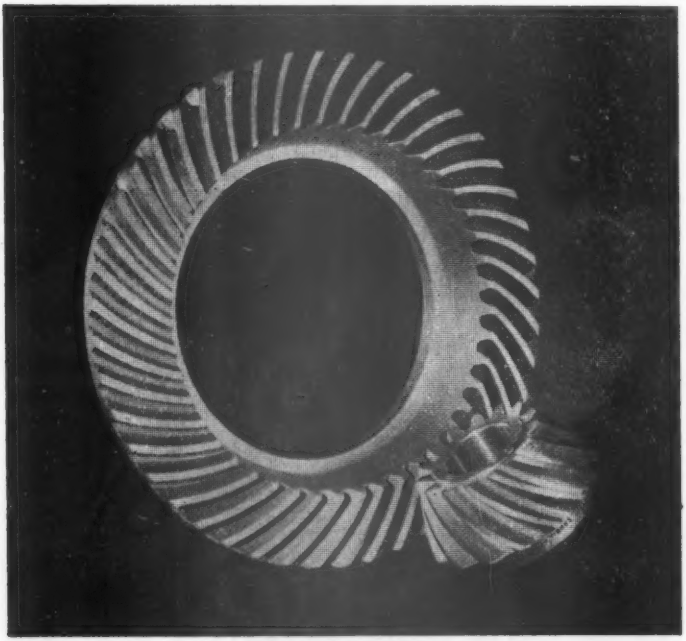


FIG. 2. Generated Spiral Bevel Gears.

Spiral bevel gears have teeth which are curved and oblique. The inclination of the teeth of spiral bevels results in gradual engagement and continuous pitch line contact or overlapping action which ensures more than one tooth in contact at all times. Because of this continuous contact the load is transmitted smoothly from tooth to tooth, which, assuming accurate manufacture, results in extreme smoothness and quietness even at very high speeds. These features result in greater load carrying capacity than can be obtained with straight bevel gears of the same size.

Spiral bevel gears are used in practically all types of equipment where it is necessary to transmit heavy loads smoothly and quietly at high speeds. They are also widely used in low speed applications where extreme smoothness of operation is an important consideration.

Zerol gears are curved tooth bevel gears with zero-degree spiral angle. In other words, the teeth are not oblique as is the case with spiral bevel gears. They are produced on the same machines and with the same type of cutters as are used for spiral bevel gears.

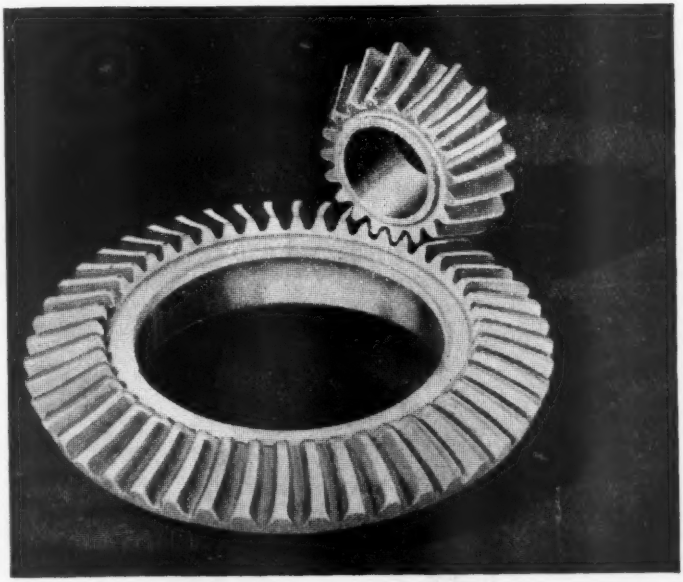


FIG. 3. Zerol Bevel Gears.

Zerol gears are generally used in the same types of drives as straight bevel gears. As in the case of straight bevels, Zerol gears have no inward axial thrust and therefore they may be used in mountings originally designed for straight bevel gears without the addition of thrust bearings. Since Zerol gears may be used in place of straight bevels, the fact that they are produced on the same equipment as spiral bevel and hypoid gears is important from the standpoint of economy, because it eliminates the need for more than one type of bevel gear cutting equipment.

When, because of design conditions, it is not possible to make adequate thrust provisions to permit the use of spiral bevels, Zerol gears are sometimes used instead, because the teeth of Zerols, up to approximately 20 in. diameter, can be ground to the accuracy required for operation at relatively high speeds.

Hypoid gears are similar to spiral bevel gears in general appearance. There is an important difference, however, in that the pinion axis of hypoid gears is offset above or below the gear axis. This feature provides many design advantages. In operation, hypoid

gears run even more smoothly and quietly than spiral bevel gears and are somewhat stronger.

FIG. 3A

Hypoid gears were first used in the automotive industry. Their use has now developed to the point where they are used in practically every automobile built in America and will be introduced in many British cars in the very near future. Their operating smoothness, due to the offset below centre of the pinion axis, has been of great importance to the automotive industry. In the general industrial field they are also very widely used, because of the many design possibilities which are offered by the ability to cross the gear and pinion shafts.

Spiral bevel, Zerol, and hypoid gears are of two types, namely, generated and formate. In appearance, they are nearly identical, the only difference between them being a slight variation in the profile shape of the teeth. In a generated pair, the teeth of both

the gear and pinion are cut with generation, whereas in a formate pair, only the pinion member is generated, the teeth of the gear being straight-sided. In generating a pinion to operate with a formate gear, the tooth profile is modified to compensate for the lack of profile curvature in the gear tooth. There is no difference in strength, smoothness, and efficiency between formate and generated gears. For tooth design reasons, the formate system is limited to ratios of approximately 3 to 1, or higher.

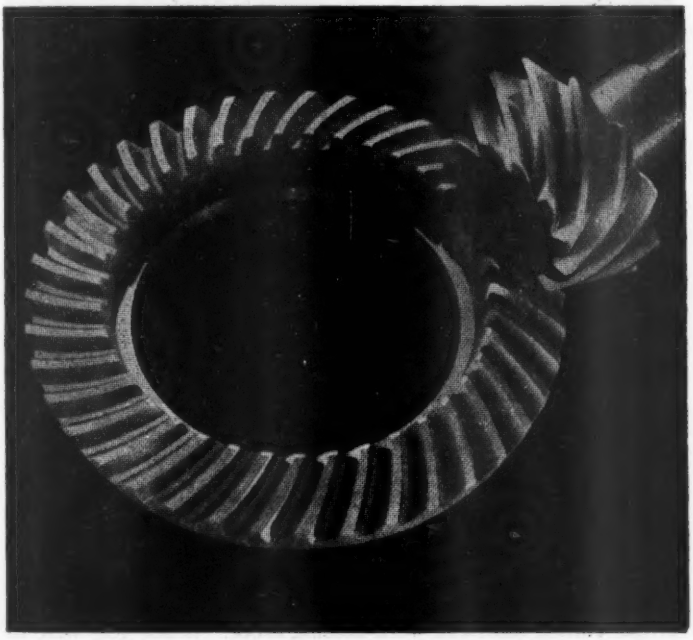


FIG. 4. Hypoid Gears.

Formate gears were developed primarily for economic reasons. Since no generating roll is required when cutting the gear member, it can be cut several times faster than a generated gear of the same specifications. It takes no longer to cut the mating pinion than it does to cut the same pinion to run with a generated gear. For these reasons, the formate type of gear is widely used in products that are manufactured in mass production quantities. Nearly all

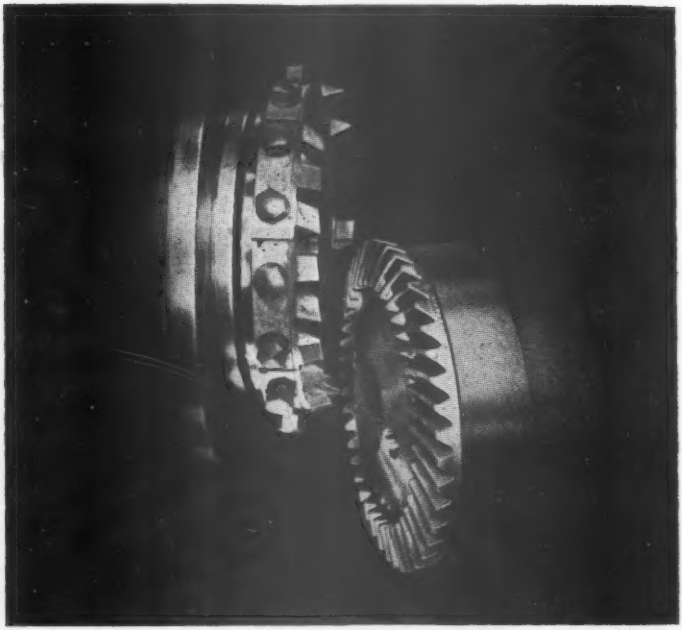


FIG. 5. Formate Bevel Gears.

American cars, and many British makes, use formate gears for the rear axle drive.

A modern bevel gear cutting machine in good condition will cut a gear which is very nearly perfect, provided that the blank is accurate and the machine is correctly set up and equipped with the proper cutting tools and work holding arbor. If this gear were to be inspected without disturbing its location on the machine on which it was cut, no appreciable eccentricity would be found. However, the gear must be removed from the cutting arbor and machine for testing, hardening, grinding of the final mounting surfaces, and other operations. It is in operations other than the cutting that many of the errors which exist in the finished gear develop. It becomes obvious then that cutting a good gear does not necessarily mean having a good finished gear unless all the operations before and after cutting the teeth are correctly performed.

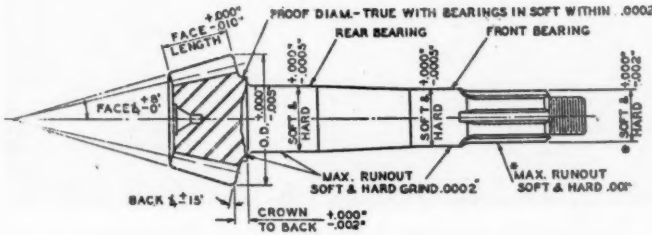
Bevel Gear Blanks.

The manufacture of a good gear must begin with a good blank. Even when the cutting of the teeth is the final operation, a correctly cut gear may be a poor gear in the assembly because of an oversize bore, run-out on the axial, locating face, or other errors in the blank.

The sequence of operations and the type of equipment used for the production of bevel gear blanks varies widely depending upon size, quantity, quality, and the shape of the gears. In general, the machining processes and the tooling used are no different than would be used in the manufacture of any other accurate machine part of a generally similar shape. In the manufacture of gear blanks the primary requirement is that the blank as delivered to the gear cutting machine should be in proper condition for cutting the teeth in accurate relation to certain important surfaces on the blank. The accuracy required in the blank should be determined by the accuracy requirements of the finished gear.

The most important surfaces on a gear blank are the surfaces which are used for locating the gear radially and axially on the gear cutting machine. As a general rule, particularly in the case of unhardened gears, these are also the surfaces which are used for mounting the gears in the final assembly. Of equal importance in the case of hardened gears are the reference or locating surfaces which are provided for use in operations subsequent to the cutting of the teeth, such as the die quenching operation and the subsequent grinding of the mounting surfaces. When the size and shape of the gear permit, it is preferable to use the same locating surfaces

PINION-SHANK TYPE



* THESE TOLERANCES USED ONLY WHEN THIS DIAMETER IS GRIPPING SURFACE FOR COLLET OF CUTTING AND TESTING CHUCKS.

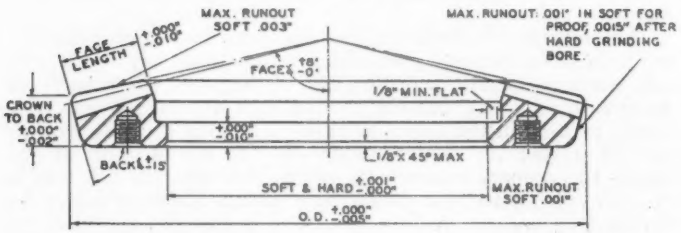
CLEAN CENTERS AFTER HARDENING AND STRAIGHTEN TO A MAXIMUM RUNOUT OF .0005" ON REAR BEARING AND .001" ON FRONT BEARING. WHEN BEARING SPACING EXCEEDS 3", THE MAXIMUM RUNOUT ON THE FRONT BEARING IS .002".

PROOF DIAMETER MUST RUN TRUE WITHIN .0005" BEFORE HARD GRINDING.

FIG. 6A

for cutting, testing, quenching, and grinding, to avoid an accumulation of errors and to eliminate the necessity of machining numerous surfaces to close tolerances.

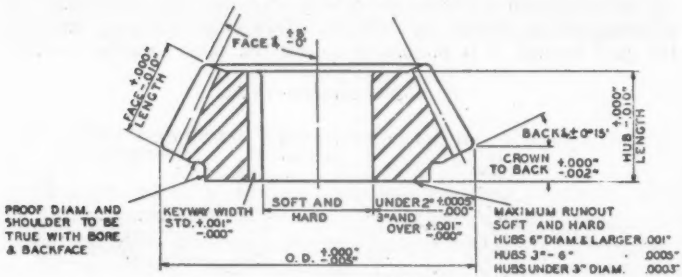
GEARS-WEBLESS TYPE


MAX. RUNOUT SOFT .003"
MAX. RUNOUT .001" IN SOFT FOR PROOF, .0015" AFTER HARD GRINDING BORE.
FACE LENGTH +.000" -.010"
FACE ± 8' -0'
CROWN TO BACK +.000" -.002"
1/8" MIN. FLAT
+.000" -.010"
BACK ± 15'
1/8" X 45° MAX
SOFT & HARD +.001" -.000"
MAX. RUNOUT SOFT .001"
O.D. +.000" -.005"

MAXIMUM OUT-OF-ROUND IN BORE IS .001" IN SOFT, .003" AFTER HARDENING BUT BEFORE GRINDING.
WHEN PLACED ON FLAT PLATE, BACK OF GEAR SHOULD BE FLAT WITHIN THE FOLLOWING LIMITS:
SOFT - .001" FEELER MUST NOT GO UNDER ANYWHERE.
HARD - .003" FEELER MUST NOT GO UNDER ANYWHERE.
BACK OF GEAR SHOULD BE HARD GROUND ONLY WHEN TEETH ARE TO BE GROUND.

FIG. 6B

PINION-BORED TYPE


FACE ± 8' -0'
FACE LENGTH +.000" -.010"
BACK ± 0°15'
HUB LENGTH +.000" -.010"
CROWN TO BACK +.000" -.002"
PROOF DIAM. AND SHOULDER TO BE TRUE WITH BORE & BACKFACE
KEYWAY WIDTH STD. +.001" -.000"
SOFT AND HARD
UNDER 2" AND OVER 3" +.001" -.000"
MAXIMUM RUNOUT SOFT AND HARD
HUBS 6" DIAM. & LARGER .001"
HUBS 3" - 6" .0005"
HUBS UNDER 3" DIAM. .0003"
O.D. +.000" -.005"

BACK FACE OF HUB SHOULD BE GROUND IN HARD IF HUB DIAMETER EXCEEDS 4". DIAMETER AND SHOULDER PROOFS MUST RUN TRUE WITHIN .0002" BEFORE GRINDING

FIG. 6C

Time does not permit the specifying of bore tolerances for all sizes and classes of gear blanks. As a general rule, in small and medium sizes, the bores of blanks for industrial gears of good quality are held to +.0005"−.0000". This would be reduced to +.0002"−.0000" for gears of a precision nature and, if extreme

precision is required, the bores should be a "wring" fit on the cutting arbor.

The radial locating surface, which in the case of the conventional type of gear blank is the back face of the hub, is fully important as the bore. It is essential that this surface be flat and true with the bore within close limits. The total axial run-out should not exceed .0005" for good quality gears of medium size and may be required to be much less in the case of precision gears.

The importance of the locating surfaces cannot be emphasized too strongly. The testing operation after cutting the teeth may become meaningless, unless it is possible to mount the gear for testing exactly the same as it was mounted when the teeth were cut. When bores are loose and axial surfaces run out, this is not possible, and much time may be lost tracing errors which exist only in the blank.

There are certain other surfaces which should be held within specified limits for the best results. Except for the radial and axial locating surfaces, these tolerances are applicable to all classes of gears other than very large gears, or to small fine pitch gears such as are used in instrument work.

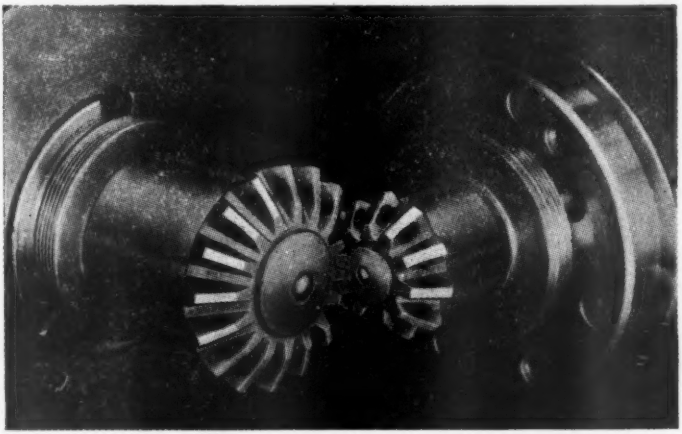


FIG. 7. Localised tooth bearing on a pair of automotive differential gears run under power in a Gleason Testing Machine.

Tooth Bearings of Bevel Gears.

One of the most important factors in the success or failure of heavily loaded gear drives is the character and the location of the tooth bearing when the gears are under load. When, because of

housing and bearing deflections or slight errors in positioning of the gears in assembly, the load becomes concentrated at one end of the teeth, early failure of the gears is almost sure to result. Since deflections take place and since it is not practical to machine and to assemble gear boxes without a working tolerance, it is desirable that tooth bearings be such that slight errors, or displacements under load, will not cause the concentration of the load at the extreme ends of the teeth.

To meet this requirement all straight bevel, spiral bevel, Zerol, and hypoid gears should have the teeth cut with a localised tooth bearing. Spiral bevel, Zerol, and hypoid gears have always been produced with this type of tooth bearing, but its application to straight bevels is a comparatively recent development.

The degree of localisation and the position of the contact area on the tooth is controlled readily in the manufacturing operations. Thus it is possible to locate the contact area on any desired portion of the tooth to compensate for known but unavoidable deflections

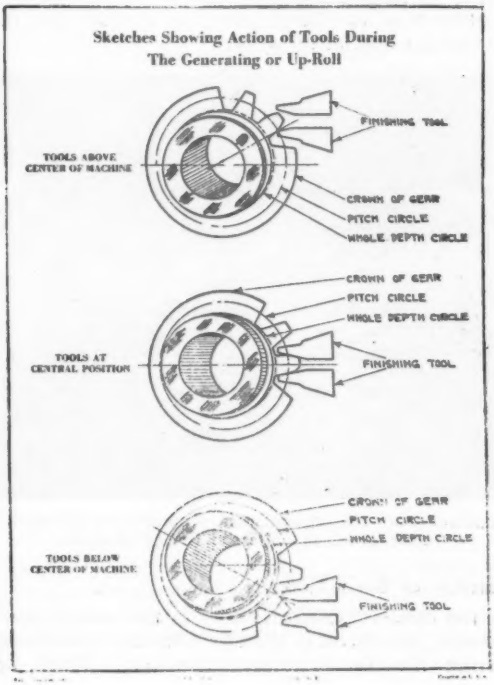


FIG. 8

of the assembly under operating load. Furthermore, allowances can be made in cutting for known changes in the tooth bearings as a result of heat treatment.

Cutting Machines and Methods—Straight Teeth.

The teeth of straight bevel gears up to approximately 35″ pitch diameter for general purpose use and for machine tools and other precision applications are usually cut by the generating process.

On these generators, the finish cutting is accomplished by two tools mounted in blocks on reciprocating slides which, in turn, are mounted on a cradle. During generation, the cradle rolls in relation with the work spindle on which the gear blank is mounted. As the tools and gear blank roll together the tools reciprocate across the face of the gear blank in a series of cuts which produces the tooth shape. At the end of the generating roll, the blank is withdrawn from engagement with the tools, and the cradle and work spindle roll back to the starting position for the next tooth. The indexing of the gear blank takes place during the return roll.

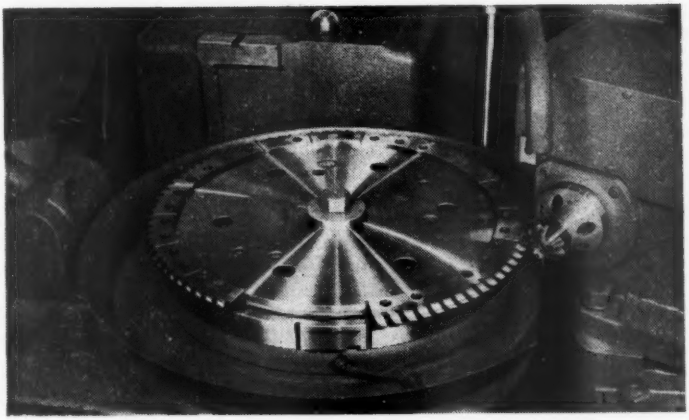


FIG. 9. Revacycle cutter in engagement with an automotive differential pinion.

One of the most unique and by far the most rapid method of cutting straight bevel gears with conjugate tooth surfaces is that known as the Gleason "Revacycle" process. Gears up to approximately 10″ pitch diameter, 5 D.P. 1″ face, are finished from the solid, no preliminary roughing being required. The "Revacycle" machine is primarily a high production machine, which in

addition to speed has the further advantage of producing a gear having the localised type of tooth bearing.

The " Revacycle " process is a method of completing generating straight bevel gear teeth in one cut from the solid metal in the case of passenger car differentials and similar gears. A large diameter, disc-type cutter is employed. The cutting blades extend radially from the cutter head, and each blade has two concave cutting edges,

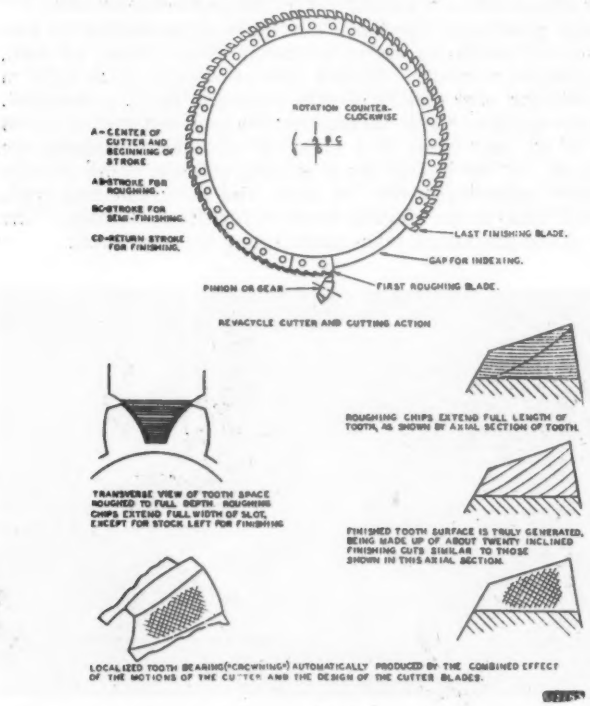

ROTATION COUNTER-CLOCKWISE
A=CENTER OF CUTTER AND BEGINNING OF STROKE
AB=STROKE FOR ROUGHING.
BC=STROKE FOR SEMI-FINISHING.
CD=RETURN STROKE FOR FINISHING.
LAST FINISHING BLADE.
GAP FOR INDEXING.
FIRST ROUGHING BLADE.
PINION OR GEAR
REVACYCLE CUTTER AND CUTTING ACTION
ROUGHING CHIPS EXTEND FULL LENGTH OF TOOTH, AS SHOWN BY AXIAL SECTION OF TOOTH.
TRANSVERSE VIEW OF TOOTH SPACE ROUGHED TO FULL DEPTH. ROUGHING CHIPS EXTEND FULL WIDTH OF SLOT, EXCEPT FOR STOCK LEFT FOR FINISHING
FINISHED TOOTH SURFACE IS TRULY GENERATED, BEING MADE UP OF ABOUT TWENTY INCLINED FINISHING CUTS SIMILAR TO THOSE SHOWN IN THIS AXIAL SECTION.
LOCALIZED TOOTH BEARING ("CROWNING") AUTOMATICALLY PRODUCED BY THE COMBINED EFFECT OF THE MOTIONS OF THE CUTTER AND THE DESIGN OF THE CUTTER BLADES.

FIG. 10

which produce convex profiles on the gear teeth. Each blade is relief ground so that it cuts the same shape after sharpening, which is effected by grinding the front face only.

The " Revacycle " cutter is mounted to rotate in a horizontal plane and turns continuously at a uniform rate. During the cutting operation, the blank is held stationary, while the cutter is moved by means of a cam in a straight line across the face of the gear or

pinion, and substantially parallel to the root line. This motion makes it possible to produce the straight tooth bottom, and the desired tooth shape is produced by the combined effect of the rotating and translating motion of the cutter and the design of the cutter blades. There is no depthwise feed of the cutter into the work, the effective depth being obtained by making each cutter blade progressively longer than the one before it.

The cutter contains three kinds of blades—roughing, semi-finishing and finishing. As mentioned before, one revolution of the cutter completes each tooth space. The very fast removal of stock by the roughing blades is made possible by the fact that these blades cut on the ends rather than on the sides, and extend for the full width of the slot at the depths where they are cutting. These blades act very much like the successive blades of a broach, taking wide and long chips.

The length of the first blade is such that it just nicks the crown of the blank. As the cutter rotates counter-clockwise, the blades gradually increase in length until full depth is reached at the root line of the tooth. Usually, about fifty of these roughing blades are employed.

The tooth space is now roughly formed at the small end, and the balance of this part of the cycle takes care of the roughing-out of the remainder of the tooth at a faster rate clear through to the large end of the tooth.

The translating movement of the cutter is reversed at this point, and the cutter is moved at a uniform rate back to its starting position. In this return movement, the finishing blades come into action and finish both sides of the space throughout the entire length of the tooth. The shape of the blades varies, each blade being suited to the position on the tooth at which it operates. By this method, the proper form of the bevel gear tooth is produced, both with regard to the tapering width and the changing profile curvature. At the same time, the blades cutting at either end of the tooth space are made slightly wider than necessary for correct taper in order to ease-off the ends of the tooth and produce straight bevel gears with localised tooth bearing, or as we have named them, " Coniflex Gears."

After the last blade has passed through the slot, there is a gap in the cutter in which the blank is indexed for the next tooth. The cutter does not stop until the gear or pinion is completed. The shape of the finished tooth surface is produced by a number of different and overlapping cuts made by successive blades. In other words, we have a generated surface. Since the blades have a concave shape, they tend to hug the tooth, reducing the number of finishing cuts necessary to produce a smooth surface. In this connection, it should be noted that " Revacycle "-cut gears are not

individually interchangeable with gears generated on the Gleason Two-Tool Generators, and must be substituted in sets. Likewise, the gear blanks must be designed for the " Revacycle " process ; but in most cases, the same mountings can be used. It is also of interest that because of the " Coniflex " bearing and the improved tooth fillets, " Revacycle "-cut differential gears are considerably stronger than the straight tooth differentials that they replace.

Cutting Machines and Methods—Curved Teeth.

Spiral bevel, Zerol, and hypoid gears are all cut on the same machines and with the same type of cutter. Two types of machines are in use ; one using the rotating face mill type of cutter with multiple blades, the other, a planing generator using a single reciprocating tool. Spiral bevel, Zerol, and hypoid gears may be cut on both types of machines.

In principle, the generating is similar to that used on straight bevel gear generators, the main difference being in the shape and action of the cutting tool. The rotating cutter is mounted on a cradle which rolls in a timed relationship with the work spindle on which the gear is mounted. The indexing of the blank to bring it into proper position for cutting the next tooth is usually accomplished during the return roll. The spiral angle and the hand of spiral are controlled by positioning the cutter relative to the work. When cutting hypoid pinions, the work head is raised or lowered from the centre position according to the amount of offset required.

A roughing cut and a finishing cut are usually required to cut a gear or pinion from a solid blank. Generally the roughing cut is made on all the blanks after which the roughed blanks are chucked again for the finishing cut. Relatively flat gears are roughed without generation, using a straight infeed of the blank into the cutter. Pinions are always roughed, using a generating roll as in finishing.

Gears of fine pitch, approximately 12 D.P. and finer, even when of precision nature, are often finished in one cut from the solid blank. Relatively coarse pitches, often as coarse as 8 D.P., also are finished in one cut from the solid when quality requirements and the machinability of the material used permit.

All generators for the production of spiral bevel, Zerol and hypoid gears may be used for roughing purposes as well as finishing. However, when relatively large quantities of gears are to be produced, it is economical from the standpoint of production, time and equipment saving to use roughing machines specially built for roughing purposes.

For roughing pinions and gears which require roughing with generation, a rougher is used which will accommodate gears up to approximately 16" in diameter, depending upon spiral angle and

cone distance. The roughing is accurate, very little stock being left for finishing, and very often pinions which are to have the teeth ground are roughed on this machine with no subsequent semi-finishing operation being required.

Gears which do not require roughing with generation, up to approximately 22″ diameter, are roughed on special gear roughing machines which are designed primarily for the rapid roughing of relatively flat gears in production quantities. No generating motion is available on these machines, the teeth being formed by the shape of the cutter.

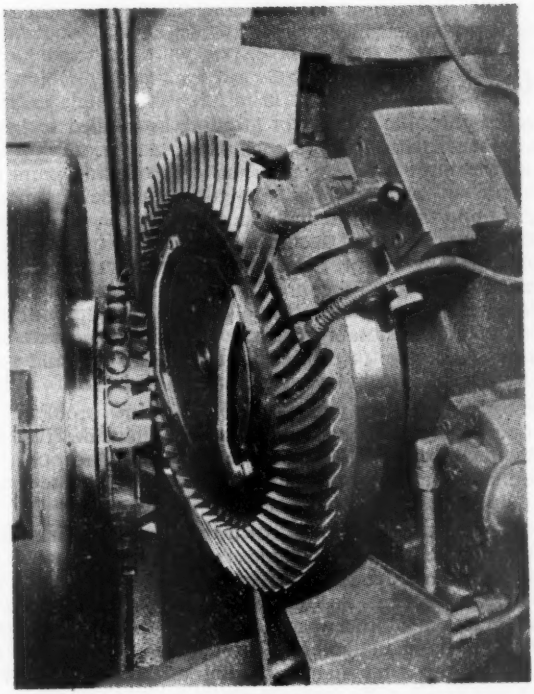


FIG. 11

Machines which are built for finish cutting purposes only are used to great advantage when production quantities are large, and when the specifications of the gear are such that the formate

shape of tooth can be adopted. These, being companion machines to the gear roughers, will also accommodate gears up to 22" diameter. The finish cutting on this type of machine is an extremely rapid operation. One tooth space is finished in each revolution of the cutter, consequently this method is known as the "Single Cycle" method. This is accomplished by the arrangement of the cutting blades in the head. Successive blades are set radially beyond the preceding blade in such a way that the cutter is in effect a circular broach. A gap between the first and the last blade is provided for indexing the work as each tooth space is completed. Thus it is not necessary for the cutter to be withdrawn from the cut, the timing being so arranged that indexing takes place when the gap is in line with the gear face.

Bevel Gear Grinding.

In recent years the process of grinding as applied to bevel gear teeth has been extensively developed and to-day grinding is in many instances the most economical means of producing gears to meet requirements of accuracy and strength. This development is of particular importance in the manufacture of hardened aircraft gears where the requirements of accuracy and uniformity are particularly difficult to meet by any other method. Grinding the teeth provides a practical solution to the problem of manufacturing extremely accurate bevel gears for aircraft application. In addition, it results in other advantages, notably smoother finish and accurate blending of the root radius into the bottom of the tooth space and the tooth profile, with a consequent increase in strength.

Grinding of the teeth has also solved many problems in the production of precision hardened gears in the industrial field, in precision instrument manufacture, in marine applications, and in the machine tool field, ground gears are used for accurate generating motions, and indexing mechanisms.

Grinding gear teeth is not an expensive operation when the work as delivered to the grinding machine is in proper condition. Unfortunately, the knowledge that the teeth of a gear are to be ground is in some cases used as an excuse or a reason for careless manufacturing practices in the operations which precede the grinding operation. In the manufacture of ground tooth gears, it is a good rule to follow the same manufacturing methods and to exercise the same care as when the teeth are not to be ground.

Bevel Gear Testing.

The most conclusive test of a bevel gear is a running test with its mate, with both members mounted in the same position relative

to each other as in assembly. Smoothness and quietness of operation, type and position of tooth bearing, tooth size, eccentricity and spacing errors can all be checked by this method of testing.

The measuring of involute tooth profile errors and lead errors which is common on individual spur gears is not a practical method for bevel gears, because the tooth of a bevel gear varies at every position from end to end, and spiral teeth do not have a constant curve. Spacing errors and eccentricity are, however, measured in much the same manner as on spur gears when it is necessary to determine the exact values.

The testing of bevel gears by running them in their correct operating position is performed on testing machines, built specially for this purpose. Two general type machines are in use, the right angle machines for testing gears which operate at 90° shaft angle, and the universal machines for running gears of any shaft angle. On most machines, one of the heads is adjustable vertically for testing hypoid gears and the other head is adjustable in a horizontal plane to handle gears of various sizes and ratios. Power is applied to one (pinion) head with a range of speeds, the driven or gear head being equipped with a brake for applying loads as the gears are run together.

The adjustments which are available on bevel gear testing machines also make them invaluable when developing the gear tooth during cutting, since it is possible to determine the amount and direction of changes necessary in the cutting machine to produce the required tooth contact. These adjustments are very useful in determining the amount and direction of errors in gear housings. The tooth bearing is observed on the gears as assembled in the housing and then duplicated on the testing machine, and the variations from the correct position are noted on the dials and scales on the machine.

Solid hand rolling fixtures are not satisfactory for testing bevel gears with the sole exception that they can be used to determine whether or not the gear being checked has backlash when mounted on correct centres with its mate or mating master gear.

The term "soft test" is commonly used to denote the running test of gears before they are hardened or heat treated. After the gears have been hardened, and lapped, if lapping is required, they are given a final running test, which is known as the "hard test." In the case of gears which are not to be hardened after cutting, the soft test is, of course, also the final test.

To maintain adequate control of quality the soft-testing operation should be performed as the gears come off the finish cutting machine. The percentage of gears tested varies in different plants and is affected by several factors, such as quality, cutting method, condition of blanks, and others. When gears are of a precision nature, it is usual to soft test and hard test 100 per cent. In any case, the

first gear off the cutting machine should always be tested after any change in the cutting conditions has been made, such as a cutter change, machine setting alteration, change in coolant or change in material.

In addition to developing the correct profile and lengthwise tooth bearing for a given pair of gears, the testing operation, particularly the soft testing, should also include an inspection of concentricity, tooth spacing, interferences, mounting distance, backlash and tooth thickness. The soft testing operation is emphasised because after the gears have been hardened it is usually impractical to remedy errors which may be discovered in the hard testing operation.

When testing bevel gears by running, excessive eccentricity is indicated by a progressive variation of the position of the tooth bearing on the teeth, and by a periodic variation in sound in time with the revolution of the gears.

Spacing errors are indicated by a knocking sound when the egars are run together, and by a very light or very heavy tooth bearing on one or more teeth.

Interferences may be detected by roughness and noisy operation and by visual observation after running with a light load. Some of the more common causes are due to teeth cut too shallow, blank machined wrongly, root radius too large, and tooth profile not entirely rolled out.

During hardening certain changes occur in the teeth which affect the tooth contact, causing the gears to run best in a position which differs slightly from the position in which the teeth were cut. Except when the mounting distance must be held exact, it is the usual practice to lap and hard test the gears in the best running position. When this position has been determined on the testing machine, the mounting distance and backlash are etched on the pinion member. When assembling the gears in the housing, the pinion is mounted as marked and the gear member is then positioned to give the backlash as marked.

In certain types of high precision gear work such as instrument gears and certain other types which are usually required to operate smoothly with little or no backlash, extremely close tolerances on tooth spacing and concentricity must be maintained. In such cases the running test may not suffice, particularly when definite tolerances must be met by measurement. To meet the inspection requirements in this field, three devices are used. These are a hand rolling tester, a tooth spacing tester, and a concentricity tester.

The hand rolling tester is the most useful device for measuring size variations, eccentricity, spacing errors and smoothness of roll. It functions on the variable centre distance principle, the head carrying the pinion being allowed to move a slight amount either side of centre. A spring arrangement applies pressure on the pinion

head in a direction which maintains metal to metal contact of the pinion with the mating gear. A dial indicator which is actuated by the floating pinion head records the errors as the gears are rotated. The readings are a composite of a number of errors and some experience is required for their correct interpretation.

The tooth spacing tester is used for measuring the variation in spacing from tooth to tooth around the gear.

The concentricity tester is a fixture for measuring the eccentricity of the teeth in relation to the axis of the bore or hub about which the gear is rotated. In principle, its construction and operation are similar to the tooth spacing tester. The fixed and movable fingers are, however, located approximately 180° apart. The difference between the highest and lowest readings in one complete revolution of the gear equals twice the run-out or four times the amount that the axis of the teeth is eccentric in relation to the axis about which the gear is rotated.

Bevel Gear Lapping.

Hardened spiral bevel and hypoid gears which are required to transmit heavy loads smoothly and quietly are nearly always lapped unless the teeth are ground after hardening. The lapping machines used may be arranged for manual, semi-automatic, or fully automatic operation depending on production requirements. The lapping compound is a mixture of abrasive and oil which is pumped to the mesh point of the gears.

The lapping operation should be used only as a means of refining the tooth surface and for correction of slight hardening changes, and improvement of the tooth bearing. It should not be considered a salvage operation for the correction of excessive hardening distortion or improper gear cutting, nor should it be relied upon to remove run-out from gears.

When lapping gears of even ratio it is necessary to identify the tooth of one member with the corresponding tooth space of the other member. In assembly, the teeth should be meshed in the same relative position as when they were lapped.

Bevel Gear Chucking Equipment.

In the cutting, testing, and lapping of bevel gears of good quality, the chucking equipment, which is used to hold the gear while these operations are being performed, plays a vital part. The importance of the holding equipment is frequently overlooked, although it should be obvious that there is no point in using a precision generator having a work spindle of great rigidity, and concentric within a fraction of a tenth of a thousandth, if the work arbor which is placed in the spindle is too flimsy to support the work adequately, or is eccentric a matter of thousandths. Many of the difficulties which are ascribed to faulty machine functioning, such as poor finish,

spacing errors and eccentricity, are eventually traced to inaccurate or incorrectly designed chucking equipment.

The important points to consider in connection with chucking equipment are rigidity, concentricity, accuracy of size, and an ample, uniform force for holding the gear in place. Excessive overhang, loose bushings, a multiplicity of fits, and equipment which must be trued up on the machine should be avoided. Chucks and arbors should, in general, be maintained within .0002″ of the correct size at all times. When mounted in the cutting or testing machine, the radial and axial locating surfaces should run true within .0002″ full indicator reading. Even closer tolerances are required for gears of extreme precision.

Bevel gear cutting and testing machines are usually equipped with a work spindle having a taper bore, which receives the taper shank of the cutting arbor. In manufacture, the large end of the bore is held very accurately to size, so that the shoulder of a correctly-made arbor will seat on the face of the work spindle, when the arbor is pulled snugly into the taper bore.

To seat properly in the taper bore and on the face of the spindle, the arbor must be made with the correct "draw." The draw is the amount that the shoulder of the arbor is away from the face of the spindle when the arbor is wrung into the spindle by hand. This amount should be from .004″ to .012″, depending on the size of the taper.

The practice of using arbors which do not seat on the face of the spindle, but locate on the taper only, is very injurious to the work spindle, and the bearings carrying the spindle. Constant use of such arbors will eventually cause the taper bore in the spindle to lose its correct size, and if such arbors are pulled into the spindle too tightly, it may cause the bearings to lock, with consequent major injury to the machine.

Nearly all modern bevel gear cutting machines are equipped with hydraulic chucks to which nearly all types of work holding equipment may be readily adapted. Hydraulic chucking was formerly used only in the automotive and other high production fields, but the advantages to be obtained through its use have caused it to be widely adopted in small lot production as well.

Bevel Gear Hardening.

One of the major problems encountered in the manufacture of accurate hardened bevel gears is that of distortion during heat treatment. From the standpoint of dimensional accuracy and concentricity, the hardening operation is generally more difficult to control than any other operation, particularly when the gears are of moderately large size and thin section. It is essential therefore that proper processes and adequate equipment be used to keep distortion to a minimum.

A gear hardening process which has been widely adopted is the localised surface hardening or flame hardening of gear teeth by means of an oxy-acetylene flame. By this method individual teeth of a gear are hardened by oxy-acetylene heating tips which heat both sides of a tooth simultaneously as they travel along the length of a tooth. No appreciable distortion can be discerned in gears hardened by this method when the process is properly applied, and in practically all cases it is safe to finish all surfaces of the gear to the final size before surface hardening. However, to attain accurate results and uniformity it is essential that machines, having the necessary adjustments for speed and direction of burner travel, be used. Surface hardening by hand is impractical because of the danger of burning and lack of uniformity of the hardening.

The surface hardening process is intended primarily for hardening the working surfaces of the teeth to increase the wear life of the gear. The hardening does not affect the core properties. When it is necessary to have a specific core strength for load carrying capacity, the gear blank must be heat treated to the required properties before finish machining.

Grinding Mounting Surfaces.

One of the most important operations in the manufacture of accurate, hardened bevel gears is the grinding of the bores, bearing diameters, and axial surfaces which are used for mounting the gears in the final assembly. Unless the teeth are to be ground, the concentricity of the teeth with the mounting surfaces, and consequently the functioning of the finished gears, are largely controlled in this operation. It is essential then that correct methods and tooling are used where finished gears of good quality are required.

There are several conditions, some of which are beyond the control of the grinder operator, which make it difficult to grind the mounting surfaces true with the teeth. Among the most common are: excessive hardening distortion, improper grinding fixtures, and improperly located or incorrectly machined reference and locating surfaces for positioning the gear for grinding.

Conclusion.

I have tried to cover in this paper the most important items in the production of bevel gears, together with some brief descriptions of the machines available for cutting, testing and heat treating the teeth.

There are two factors, however, which should be considered all important. First, accuracy of blanks, and secondly the necessity, of developing the tooth bearing best suited for the particular application.

A pair of gears can only be as good as its tooth bearing when in their final mounting in service.

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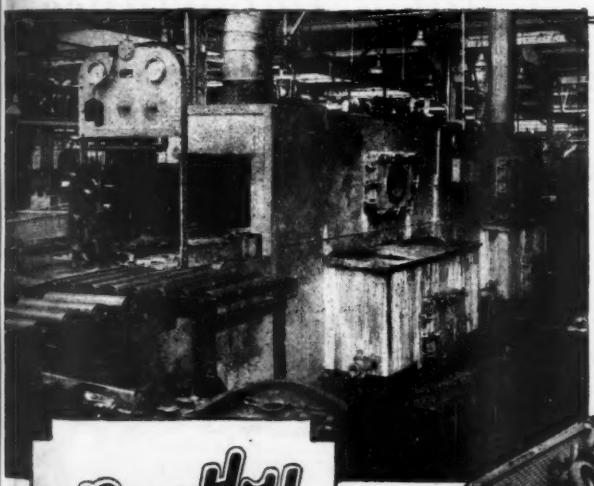

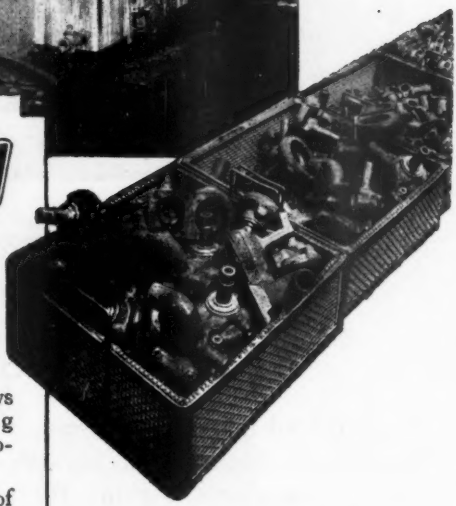

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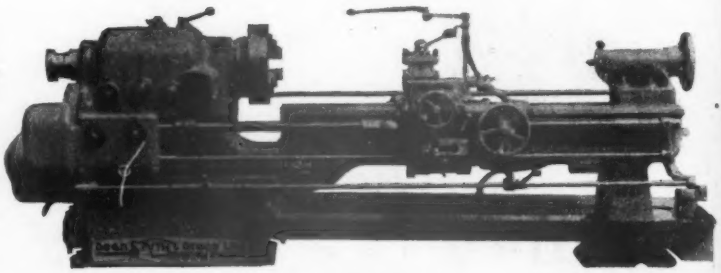

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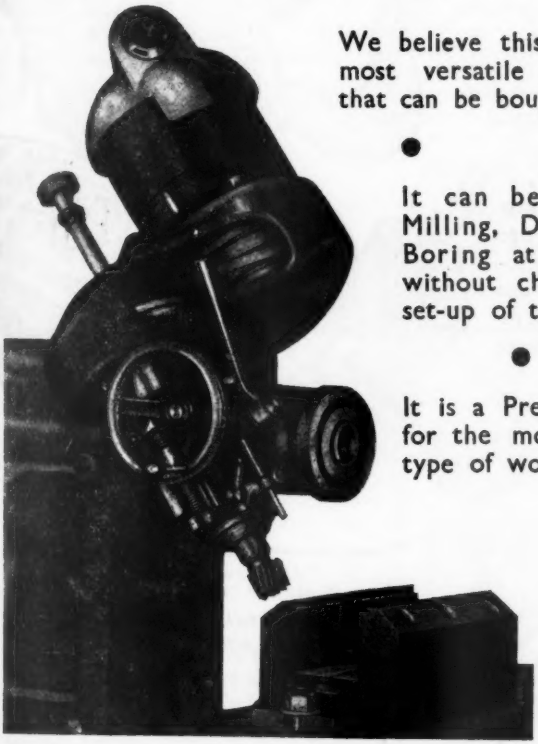

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Hoots Toots ! (says the M.D. in what he imagines to be a Scots accent). A gey clever laddie was oor Rabbie. If ye could see yoursel' the noo, ditherin' and mitherin' wi' that auld puddock of a tool and michty pleased wi' yoursel', nae doot ! D'ye no ken that therre are fine wee toolies workin' wi' elec-trricity and such that wad dae your worrk in hauf the time at a huge savin' o' bawbees ! Losh, mon, if ye could juist see yoursel . . . !

Cor, stone the crows mate ! If you could take a gander at yerself you'd take a runnin' jump into the Frith of Froth !

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How to make the best use of Electricity this Winter

Now that we all realise that there's a very real danger of Electricity cuts throughout this winter, it is essential for everyone to know how to manage with the minimum of inconvenience and discomfort.

This is the problem . . .

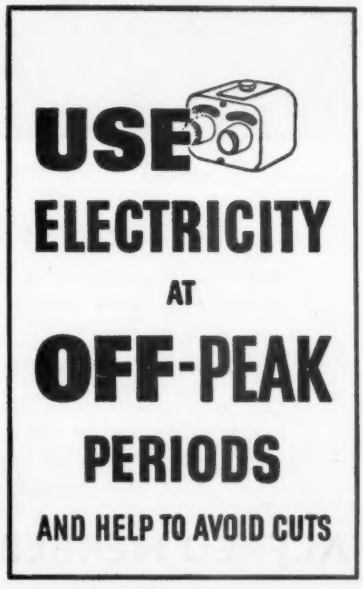
The problem is a very straightforward one. There is not enough Electricity-producing machinery to meet every demand, all the time. Why? Because for six years no extensions or additions to the Power Stations were allowed unless directly needed for helping towards Victory; *none* were allowed for the anticipated higher post-war demands. A vast power plant project, costing over £200,000,000, is now in hand, but this will take *time*. Meantime, the war-tired plant must not be over-strained: if too many people are using Electricity simultaneously, the Electricity engineers *must* switch off for a while.

. . . and THIS is the solution

Don't over-burden the willing horse. Electricity will go on giving you the same faithful service if you'll do *your* part. The heaviest burden comes in the PEAK PERIODS, and if everyone will honestly plan to lighten the load in these periods, *the danger point may not be reached.* At present the PEAK PERIODS are from 8 a.m. until noon, and from 4 until 6 p.m., for five days a week — Monday to Friday. If everyone will transfer some Electrical load to OFF-peak periods, we may avoid some of the cuts. Here's how *you* can help relieve the strain. Just adjust your daily routine so that OFF-peak periods are always the Electricity-using times, and peak periods are the *helping* times. It may perhaps mean inconvenience to you: nobody likes having their carefully-arranged daily programme upset. But it's truly worth it. It is a fact that your Power Station, just now, is relying upon the help that you can give.

No strain means no cuts

If you *do* get cuts you'll know that some people *aren't* helping. But — cuts may well be avoided if everyone helps!



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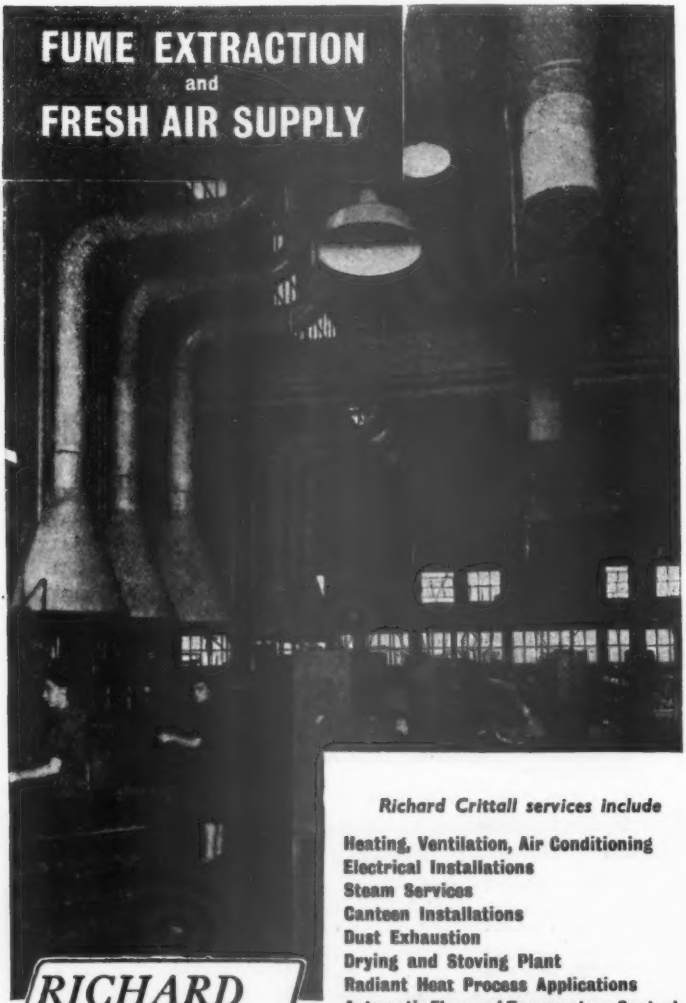

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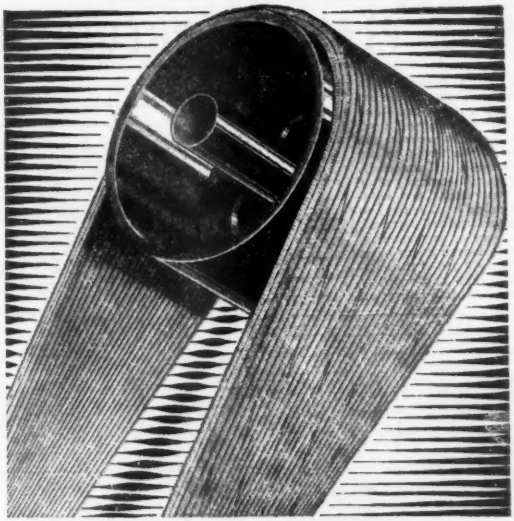

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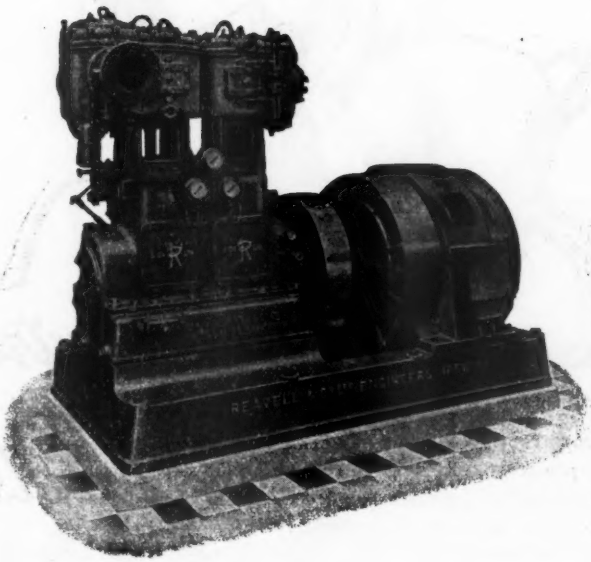

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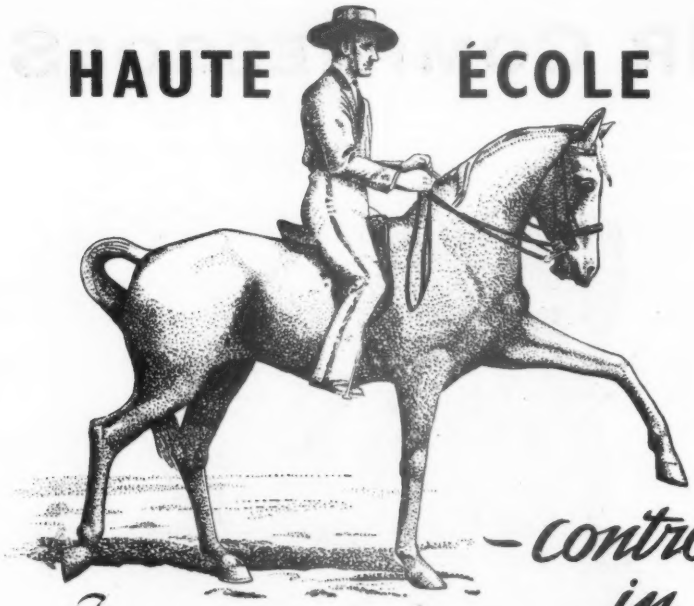

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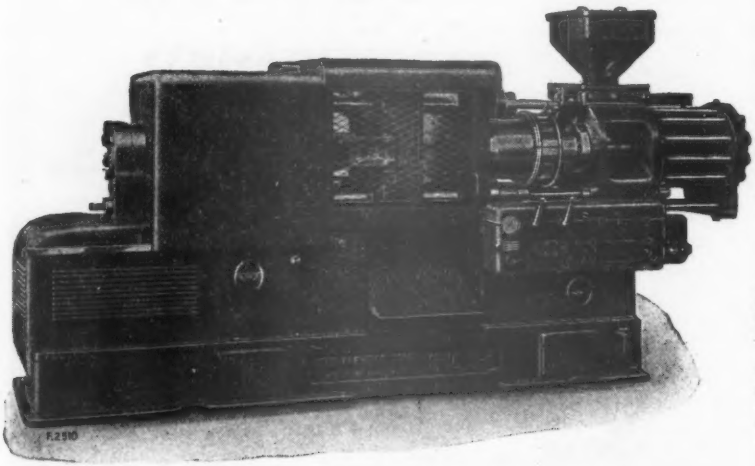

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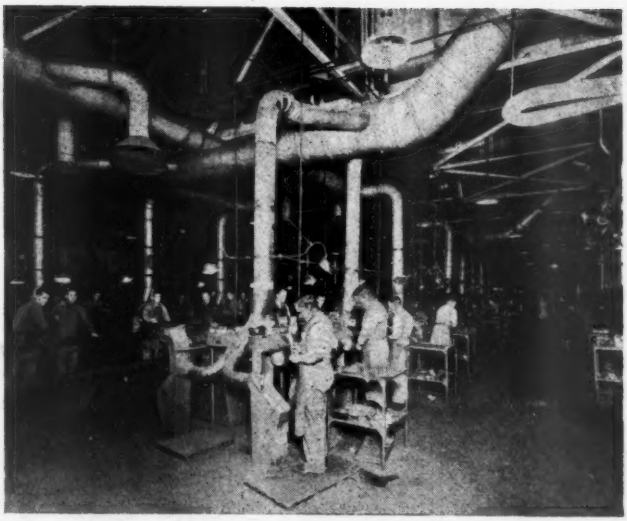

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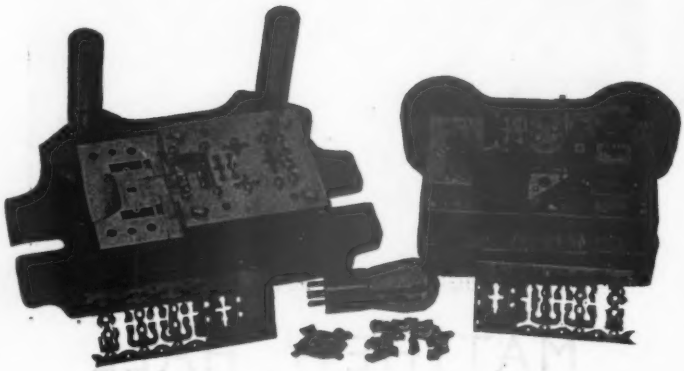

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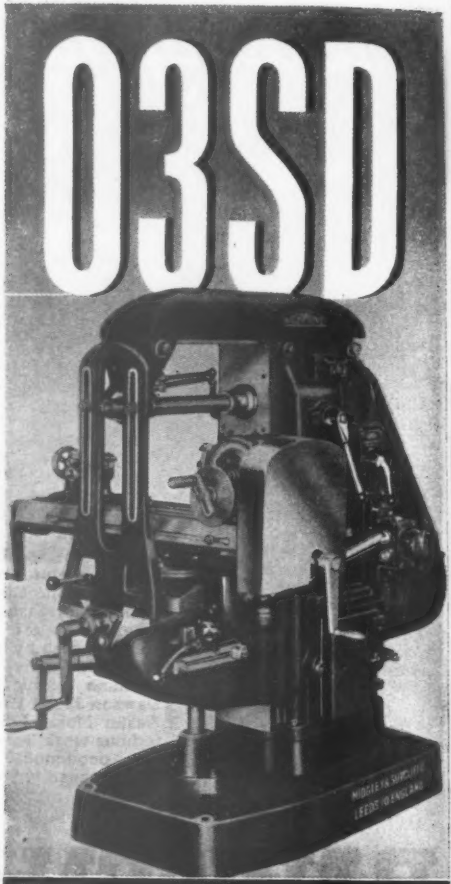

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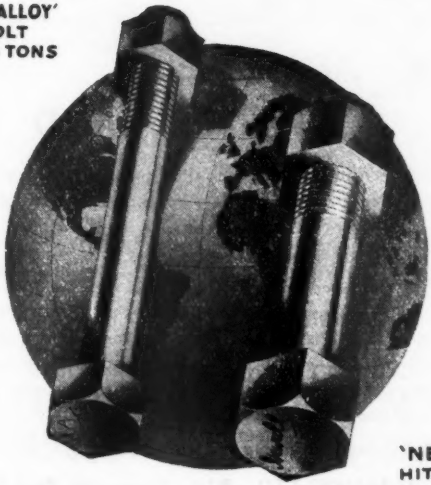

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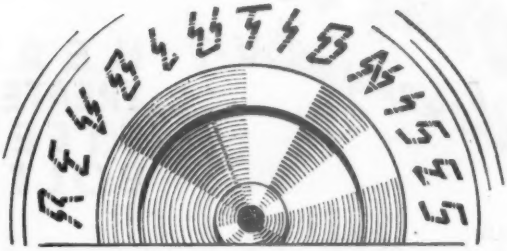

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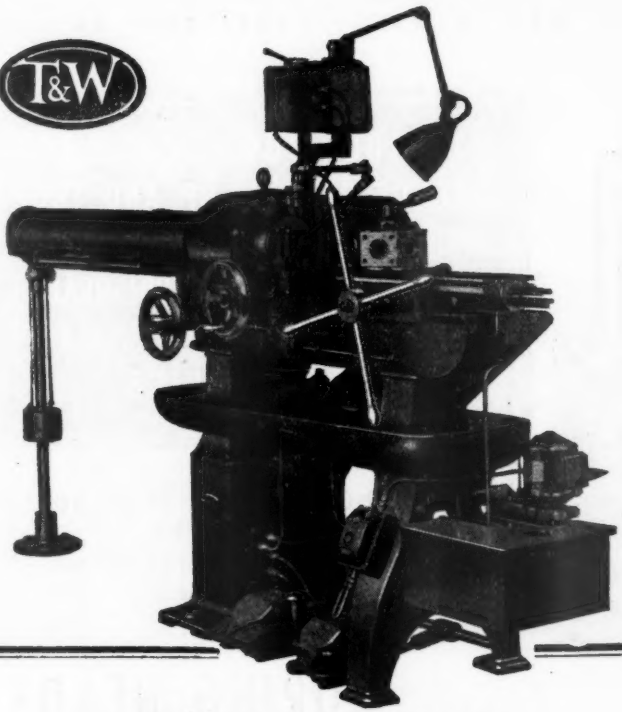

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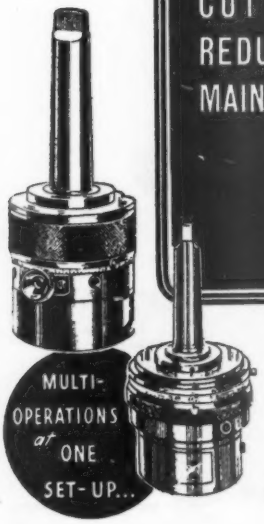

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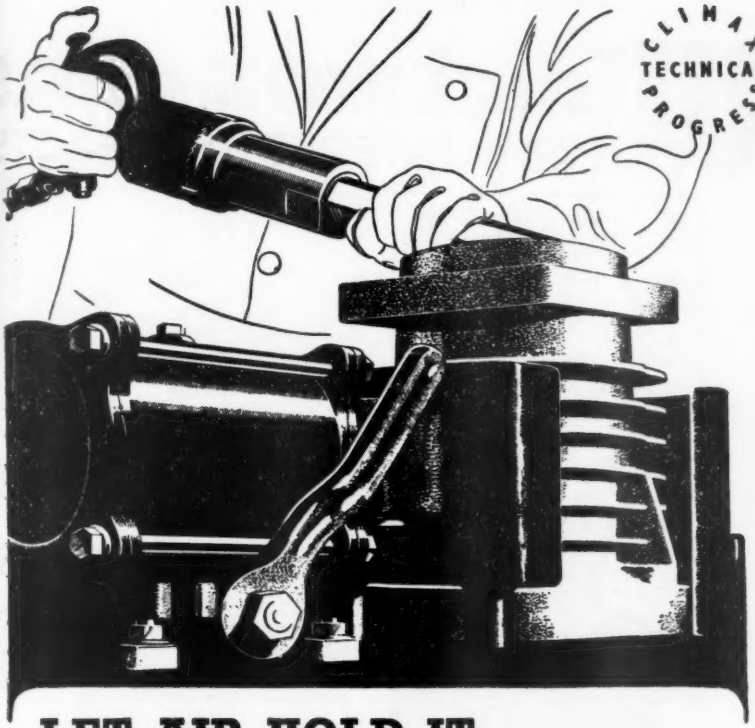

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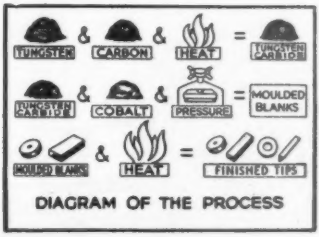

DIAGRAM OF THE PROCESS

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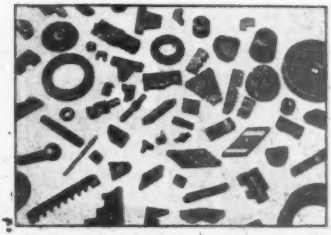

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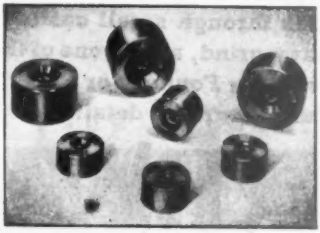

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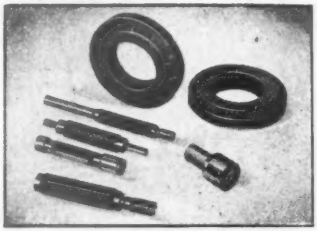

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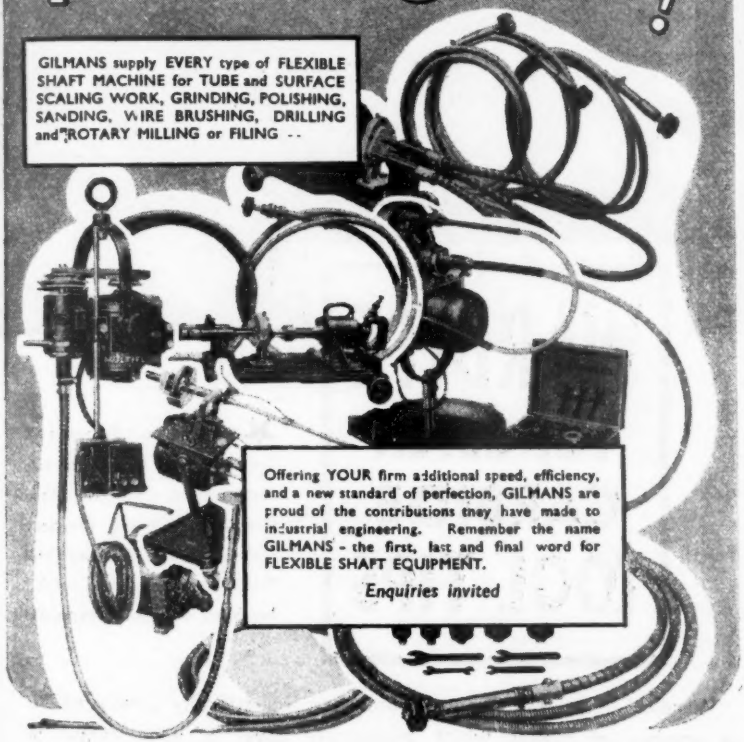

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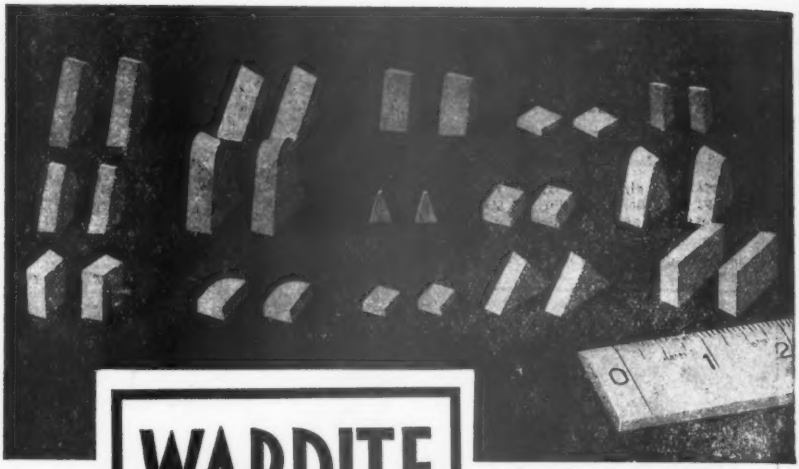

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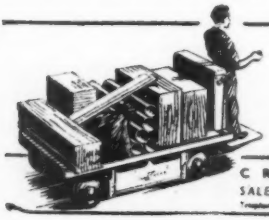

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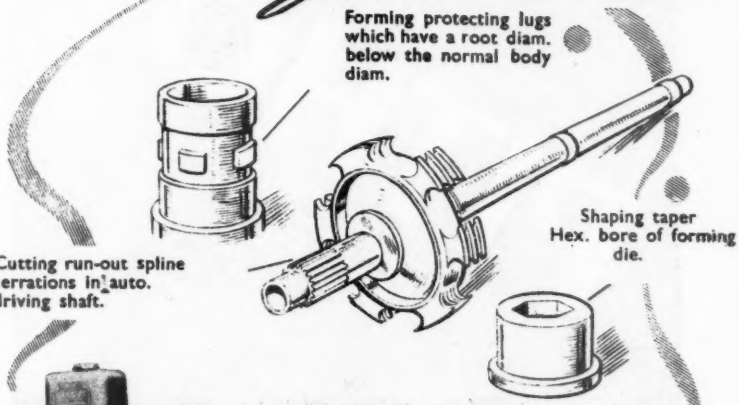
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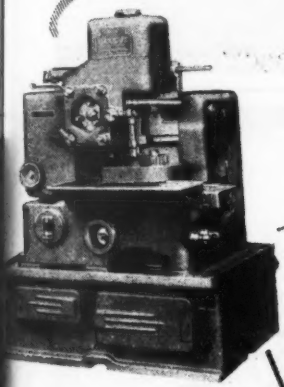

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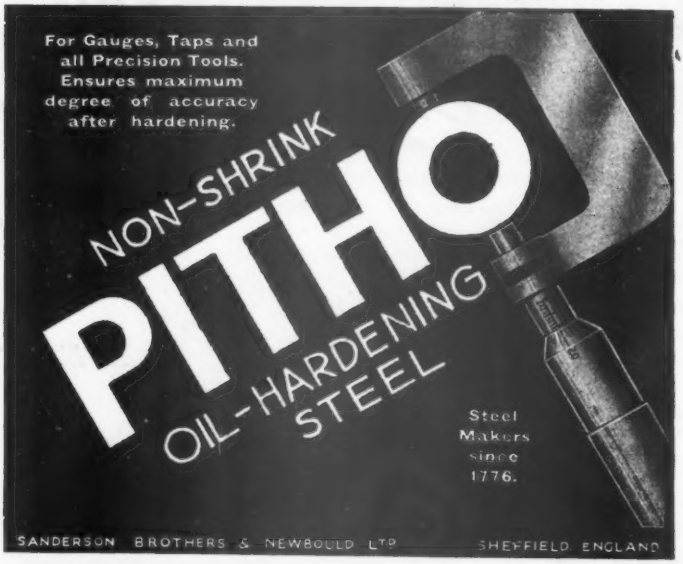
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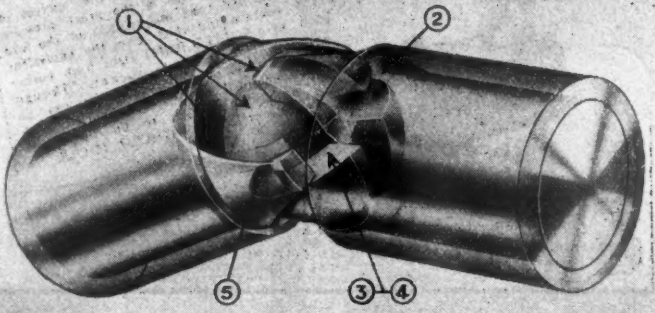

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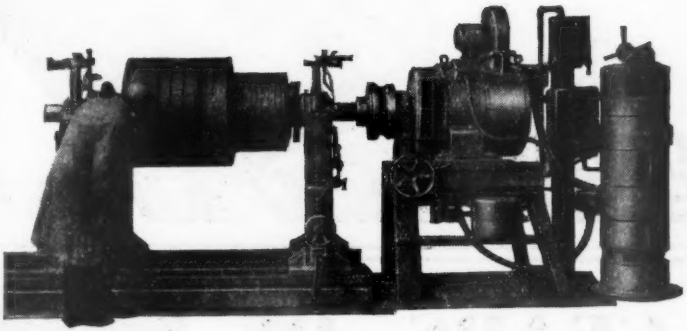

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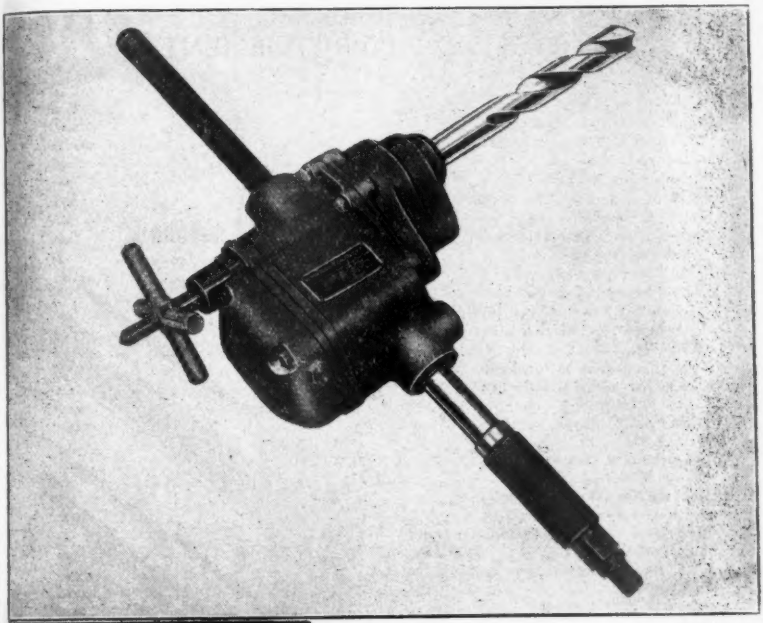

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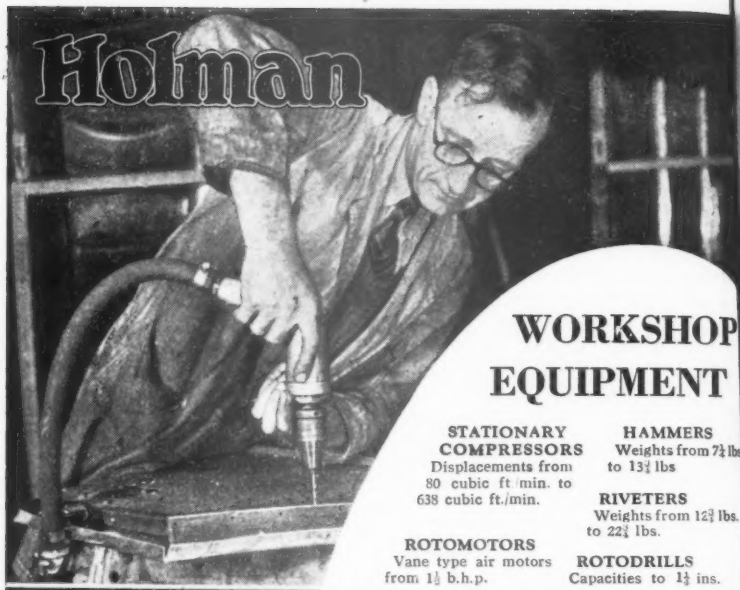

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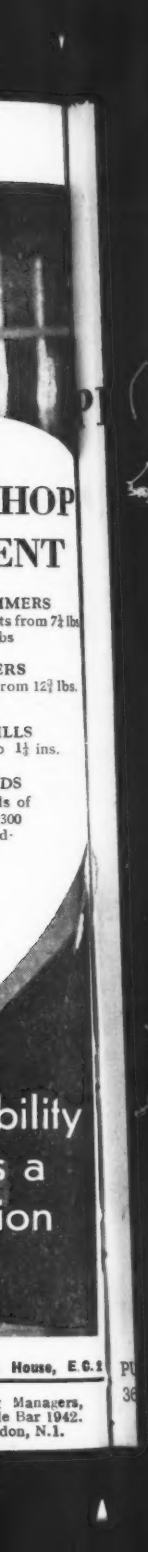
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